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The Transient Response of a Distillation Column to Liquid Rate Perturbations.

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THE TRANSIENT RESPONSE OF A DISTILLATION COLUMN TO LIQUID RATE PERTURBATIONS

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ABSTRACT

In order to more effectively design distillation equipment and in order to better control distillation columns, it is necessary to understand the dynamic behavior of distillation equipment when transient conditions are present within the equipment. This paper presents a study of the transient response of a rectangular section of a plate-type distillation column when changes occur in the flow rate of reflux to the column.

This study was made on an 8 inch by 20 inch column containing 5 sieve trays on 12 inch spacings, and the column was separating a binary mixture of acetone and benzene.

In preparation for a specific run, the column was operated at total reflux until steady state conditions were achieved. At this point a step change, either increase or decrease, was introduced in the reflux flow rate to the column without altering either the reflux composition or temperature. As the column responded to this change, samples of tray liquid were removed from the top, middle, and bottom trays at timed intervals until a new steady state was achieved.

A series of such runs was made on the column with the column trays having 3 inch outlet weirs and in which changes in reflux flow rate were made of 7.1 per cent to 82.8 per cent step increases and -12.0 per cent to -31.2 per cent step decreases. The tray outlet weir heights were then changed to 1.5 inches and a series of runs was made

in which changes in reflux flow rate were made of +8.6 per cent to +21.5 per cent step increases and -15.6 per cent to -20.0 per cent step decreases.

The results of these runs, i.e., tray composition versus time data, were then fitted to decaying exponential type curves by least squares techniques. The resulting curves each yielded a value of a time constant, i.e., the time in which 63.2 per cent of the transient change had occurred. These time constants were then correlated in the dimensionless form of (time constant)x(liquid flow rate)/(tray hold-up), and the resulting dimensionless number itself was correlated with the vapor F factor. (The F factor was calculated as the vapor superficial velocity multiplied by the square root of the vapor density.) The resulting values of F factor versus dimensionless number were then fitted to a straight line by least squares techniques.

This type of straight line relationship between the time constant factor and the F factor was determined for individual trays and individual weir heights and for the hold-up on the tray deck alone and for tray hold-up plus downcomer hold-up. They were also determined for the column as a whole without regard to tray location and weir height. These final correlations were checked by using their predicted response as a comparison with the experimentally determined response. Agreement was quite good.

Based on the behavior observed, it was concluded that (1) when a small number of trays are considered, tray position is not important in predicting tray response, (2) a simple linear lag is sufficient for correlating response to liquid flow rate fluctuations, (3) the time

constant associated with the linear lag is not dependent on direction or magnitude of the change in liquid rate, (4) the time constant of the lag correlates well in the dimensionless form mentioned above, (5) the time constant correlates well with the vapor F factor, and (6) slightly better results are achieved when downcomer hold-up is included in the correlation.

CHAPTER I

INTRODUCTION AND AIMS[8,15,16]

Distillation is the separation by vaporization of the components of a mixture. The basic area of distillation with which this work is concerned is that area known as continuous rectification or "fractionation;" and a typical industrial type of continuous fractionating column, complete with the necessary auxiliaries, is shown in Figure 1.

The majority of the applications of continuous rectification are found in the separation of one or more of the components of mixtures of organic compounds. There are, however, some industrially important applications in the purely inorganic area such as the separation of liquid air or the recovery of ammonia from ammonia liquor.

The design of equipment to perform separations via continuous rectification is very complicated. To gain insight into the nature of the problem, it is advantageous to list the factors which govern the completeness of separation of a mixture. They are:

(a). The volatilities of the components of the mixture.

(b). The ratio of reflux downflow rate to the rising vapor rate.

(c). The length of the contact path.

(d). The efficiency of the contact.[16]

Item (a) depends upon the nature of the specific components

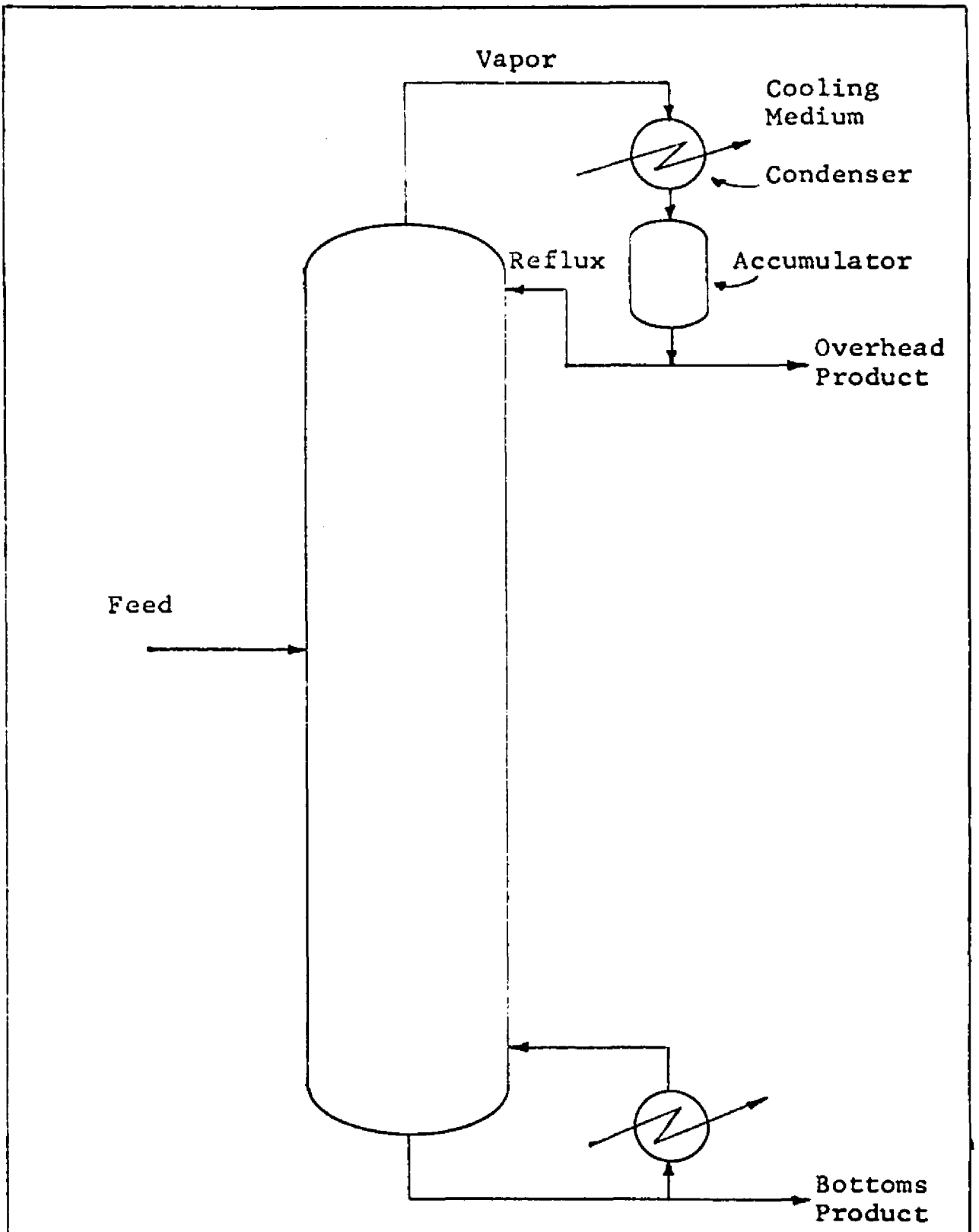


Figure 1. Continuous Fractionating Column.

encountered in the mixture; item (b) depends primarily upon economic considerations, i.e., increasing the reflux will decrease the column height but increase the cross sectional area and increase the rate of heat input necessary; and items (c) and (d) are determined (for a given reflux rate) by the type of internal construction employed.

The types of internal construction available usually fall into two broad categories: plate columns and packed columns. Plate columns are the columns to which this research is limited.

The actual design of plate type columns can be separated into two broad areas: one, the determination of the number of equilibrium stages required and the reflux necessary, and two, the determination of the number of actual stages required and the particular column geometry to be employed.

Equilibrium stage and reflux requirements are basically determined by repeated application, to each stage in turn, of:

(a). Material balances.

(b). Enthalpy balances.

(c). Vapor-liquid equilibrium relationships.

The application of these three to a binary or multicomponent mixture is a relatively straightforward, although sometimes lengthy and tedious, process. Rather than enumerate the many available approaches to this basic area, the reader is directed to any distillation textbook.

The second broad area of the column design problem, the determination of the actual stages required and the particular column geometry to be employed, is on a less fundamental basis than the first area.

The design engineer is called upon to use mainly empirical correlations coupled with a prudent blend of judgment, experience, and "safety factors." For a lucid presentation of the problem, the reader is referred to Hengstebeck's textbook.[8]

In taking a broad view of the total design problem of a continuous rectification column, there is one general basic assumption which seems to prevail--every consideration is based upon the column existing in a rather permanent condition of "steady state," i.e., no variables within the column are changing with time. When consideration is given to the start-up and shut-down periods, the ever-present action of controllers, the inherent fluctuations of process conditions, and the basic changes to the process that are operator imposed, then it can be seen that "steady state" is a very idealized situation.

That this dynamic or non-steady-state condition has been assumed out of existence is, more often than not, a matter of necessity. It is a very complicated area and it requires a high degree of sophistication in its treatment. It is an area about which, even today, very little is known. Our inadequacy in this area presents itself in a number of ways, such as the need to "over-design" to care for dynamic behavior, poorer control, lower yields, lower return on investment, et cetera. In our present era of keener competition, rigid product specification, and sophisticated control availability, it is evident that more attention must be given to the area of dynamic behavior. It is because of this basic need that this research was undertaken.

Some introductory consideration should also be given to the area of rectification column control because here again, and for even more obvious reasons, the subject of dynamic behavior comes into focus.

To gain insight into the problems connected with control of dynamic behavior, it is helpful to consider the variables inherent in distillation operation. For a specified distillation column with a definite number of plates and a definite size, which is operated in the most effective manner, and in which there is no heat transfer to the atmosphere, there are six independent operating variables. Refer to Table I. If it were possible to consider each of these six independent variables as constant, then the separation for which the column was designed would be achieved with no further concern. In view of the transient conditions previously mentioned, this is an impossibility and column control is necessary. For a summary on how to achieve this control, the reader is referred to an excellent article by Hoffman.(9)

Since column control is necessary, it follows that to get the maximum effectiveness, and in many cases to get any semblance of satisfactory results at all, it is necessary to know how changes in the independent variables will change the dependent variables--not only what their final value will be, but, equally important, how the change will occur. This need provides further justification and incentive for the undertaking of this research project.

The entire area of process dynamics has received much attention lately, and it is interesting to note that recently the American Institute of Chemical Engineers' Research Committee decided to attempt to sponsor a research project into the subject. Their specific area of research was in distillation dynamics, and it is interesting to note one paragraph of their letter announcing the decision.

> In selecting this proposed project of process dynamics the Research Committee was guided by the fact that lack of a firm

TABLE I

DISTILLATION VARIABLES[29]

External Independent Variables

1. Feed rate.
2. Feed composition.
3. Feed temperature or quality.
4. Ambient pressure of operations.

Internal Independent Variables

5, 6. Two of the following four quantities:

(a) Overhead product composition (complete).

(b) Bottoms composition (complete).

(c) Boil up rate--feed rate ratio.

(d) Feed split or distillate--bottoms ratio.

Dependent Variables

1. All liquid compositions not already specified.
2. Vapor compositions at each location.
3. Temperatures at each location.
4. All unspecified flow rates.

Semi-independent Variables of Column Operation

1. Feed tray location.
2. Column reflux temperature or cooling water temperature.
3. Steam pressure.

(These can affect column control but are considered constant.)

> knowledge of the transient behavior of chemical process equipment is frequently the weakest link in the design of the process equipment and automatic control systems of process units. Distillation systems were singled out for specific study because of their complexity and their prevalence in nearly all processes and because several chemical engineering regimes will be involved such as mass transfer, heat transfer, flow of fluids, etc. Also the conclusions obtained here will have applicability to other stagewise operations.[1]

With this statement serving as an introduction to the subject, the major aims of this research project can now be stated:

1. To design, fabricate, instrument, and operate an experimental distillation column which will facilitate the experimental study of transient conditions which occur in a column.
2. To experimentally study and correlate the response of this distillation column to liquid flow rate perturbations.

To these ends this research project has been directed.

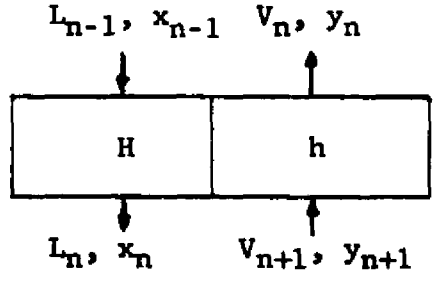
CHAPTER II

THEORY

1. Basic Equations

To understand the basic problems inherent in the study of distillation plate-column dynamics, it is useful to develop a set of basic equations which describe the mass transfer process occurring within each equilibrium stage. These equations will not necessarily be used specifically to correlate column response characteristics, but they will serve to illustrate some of the problems involved. The material balance equations will be developed, but the complete differential enthalpy balance will be ignored since it does not introduce anything useful as far as the equation concept is concerned.

It is necessary to write a material balance for each component except one on each stage:



$$\frac{d(H_n x_n)}{dt} + \frac{d(h_n y_n)}{dt} = V_{n+1}y_{n+1} + L_{n-1}x_{n-1} - L_n x_n - V_n y_n \qquad \text{(II-1)}$$

where H_n = hold-up of liquid on stage n in lb-mols

h_n = hold-up of vapor on stage n in lb-mols

It is also necessary to use the equilibrium relationship:

$$y_n = f(x_n) \qquad \text{(II-2)}$$

A number of simplifying assumptions may be applied to equation (II-1). If the following assumptions are made:

(a). $H_n = H_{n+1} = H_{n-1} \cdots$

(b). $h_n = h_{n+1} = h_{n-1} \cdots$

(c). $L_n = L_{n-1} = L_{n+1} \cdots$

(d). $V_n = V_{n-1} = V_{n+1} \cdots$

Then (II-1) becomes:

$$H\frac{dx_n}{dt} + h\frac{dy_n}{dt} = Vy_{n+1} + Lx_{n-1} - Lx_n - Vy_n \qquad \text{(II-3)}$$

If it is further assumed that:

(e). $h = 0$

(f). In the range of interest the equilibrium relationship may be considered as linear, i.e., $y_n = ax_n + b$ where a and b are constants.

Then (II-3) becomes:

$$H\frac{dx_n}{dt} = V(ax_{n+1} + b) + Lx_{n-1} - Lx_n - V(ax_n + b)$$

$$= aVx_{n+1} + Lx_{n-1} - Lx_n - aVx_n$$

or

$$(HD + L + aV)x_n = aVx_{n+1} + Lx_{n-1} \qquad \text{(II-4)}$$

where $D = \frac{d}{dt}$, the differential operator.

The initial or boundary value conditions which can be applied to a representative equation such as (II-4) will depend primarily upon the physical arrangement of the distillation equipment. Considering

equation (II-4) itself, there are two points worthy of note: one, a number of simplifying assumptions have already been made to reduce it to its present form, and two, it should be re-emphasized that the complete application of this material balance must be made to all but one component on every stage in the column. The reader can easily see that the solution of this simplified simultaneous set of linear equations is a very formidable task, and it is no wonder that we have such a small amount of outstanding work recorded in the field of distillation dynamics.

Some of the more common techniques used in the solution of these equations deserve comment:

(a) Analytical solution--this includes classical solution means, transformation techniques, and established short-cut methods such as those of Ziegler and Nichols.

(b) Perturbation methods--these consist in studying small departures from the equilibrium condition. They are especially useful in studying automatic control problems.

(c) Graphical methods--these usually entail a considerable amount of work and are too inaccurate for numerical solutions, but they do give insight into behavior patterns.

(d) Analog computers--these have limited accuracy, and depending on the computer installation available, are often limited to a relatively small number of plates.

(e) Digital computers--provided that the equations define a physical solution (which they should), they can always be solved on a digital computer, though not necessarily in an economic time.

(f) By-passing the equations completely and establishing a simple empirical model.

It should be noted that techniques (a) and (c) are virtually impossible for non-linear equations of any complexity, and unfortunately, the accurate representation of the correct column behavior will necessitate the solution of non-linear equations.

The subject of mathematical representation and solution will be discussed more fully in Section 3 of this Chapter. With this brief outline of what can be involved in one approach to the basic problem, it will now be profitable to consider the approach used by three previous investigators.

2. Previous Work[2,28]

For a very complete and relatively up-to-date bibliography and analysis of the state of the art of distillation dynamics, the reader is directed to the work of Archer and Rothfus.[2] In their work they point out an important fact relative to the previous work done in the investigation of distillation column response. They note that the bulk of research in the area of distillation column response has been centered upon the interrelation of composition transients as a function of boundary value compositions, and the assumption of constant flow rates with the column has been very prevalent, e.g., the effect of varying flow rates on compositions has not been studied to any extensive degree. The only information concerning this important area has come from several computer studies and a small amount of experimental information. Three works involving experimental studies and employing different methods of attack will be briefly reviewed here.

Armstrong and Wilkinson[3] made an experimental study of, among other transients imposed, the response of a 21 plate distillation column to changes in reflux flow rate. Their column was 4 inches in nominal diameter and bubble cap trays were installed on a 6 inch spacing. They made their experimental studies on one mechanical configuration, one binary system, and always introduced a liquid rate change by going from total reflux to a 10:1 reflux ratio. They correlated their experimental data in terms of a delay time followed by a single exponential transfer stage or simple linear lag. The open loop transfer function was, therefore, of the form:

$$X(s) = \frac{e^{-T_1 s}}{1 + T_2 s} \qquad \text{(II-5)}$$

where s = the complex variable in the Laplace transformation.

Note that this approach completely side steps the need for a theoretical model. This will be discussed further in Section 3 of this Chapter.

A total of twelve time constant pairs were evaluated and compared to the tray position which they represented. Several items of note were observed:

(a) Response is much faster for flow rate perturbations than for previously determined responses to concentration perturbations.

(b) The variation of response with plate number is very slight. T_1 was only 7.69% of T_2 for plate 14 in the column, for example.

The second experimental study of the response of a distillation column to flow rate variations to be discussed is the work of Baber and

Gerster.[4] Their studies were based on data from a bubble cap column 2 feet in diameter and containing 5 trays on 24 inch spacing. They made studies on one mechanical configuration, one binary system, and they studied step increases in liquid rate. The maximum change studied was an increase of 8.6% in liquid flow rate.

Baber and Gerster studied the response which they experienced in terms of the perturbation equations of Lamb, et al.[13] These equations assume that changes in pressure, composition, and temperature within the distillation system can be expressed as small, linear perturbations from a steady state value. For the case of a constant 100% tray efficiency, negligible vapor hold-up, and completely mixed tray liquid, the equation for a typical tray n reduces to:

$$\frac{dx_n^p}{d\theta} = (x_{n-1}^o - x_n^o)\,(L_{n-1}^p / L_n^o) - y_n^o\,(V_n^p / L_n^o) + y_{n+1}^o\,(V_{n+1}^p / L_n^o) + x_{n-1}^p\,(L_{n-1}^o / L_n^o) + m_{n+1}x_{n+1}^p\,(V_{n+1}^o / L_n^o) - x_n^p\,(1 + \frac{V_n^o}{L_n^o} m_n) \qquad \text{(II-6)}$$

Liquid perturbations on adjacent trays are related to each other by the relationship:

$$\frac{dL_n^p}{d\theta} = (1/B_n)(L_{n-1}^p - L_n^p) \qquad \text{(II-7)}$$

where

$$B_n = (L_n^o/H_n^o)(dH_n^o/dL_n^o)$$

Several results achieved seem relevant to this research project:

(a) It was satisfactory to assume that a liquid rate perturbation to the top tray was felt immediately by all other trays, i.e., $B_n = 0$.

(b) The absolute average of deviations of observed composition from predicted composition was 0.37 mol % and the average total change between initial composition and final composition was approximately 5 mol %.

The third experimental study to be briefly discussed is that of Huckaba, et al.[11] They proposed a model for a contacting stage by assuming the plate to behave as a simple mixer-separator stage and then applying the equations describing the simplified model of one stage to a set of interconnected stages which go to make up a complete distillation column. The resulting equations were solved via a digital computer, and the results were compared to some experimental data. Very few details of the comparison of predicted results to experimental data were presented; however, the agreement seemed to be good at the ends of their column. In the center of the column, the agreement was not quite as good but the difference was never in excess of 4 per cent.

This author feels that the outstanding feature of their study was the derivation of the mathematical model for the column and the consequent solution of the model via a digital computer.

3. Developing a Mathematical Model[2,28]

Probably no more lucid work exists concerning frationator models than that of Williams,[28] and many of the basic ideas presented in this section must be attributed to him.

Williams points out that there are three basic ways to represent the dynamic response of any stagewise process:

(a) By overall transfer functions relating a chosen dependent variable to one or more independent variables.

(b) By a complete, theoretical mathematical model based, of course, on a particular set of assumptions. This will result in a set of differential equations relating the pertinent variables.

(c) By a theoretical model for each section of the column--such as in (b)--and the individual action of each section is considered to be independent, or subsequent to, the action of other sections.

The first two of these basic means are demonstrated in Figure 2. The methods are broken down in order of increasing exactness, and unfortunately, in order of increasing difficulty.

The transfer function model is the only one of these to be discussed here since this is the type of approach used in this research project.

The transfer function model is the one which is most adaptable to the representation of experimental data,[28] but it does have the characteristic of yielding an empirical model. This empiricism, while unacceptable to some investigators, is not necessarily bad in itself, and the route to any true model will probably combine both theory and empiricism as noted in Figure 3.

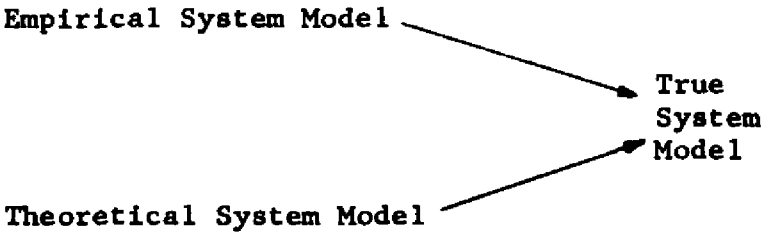


Figure 3. Route to a True System Model

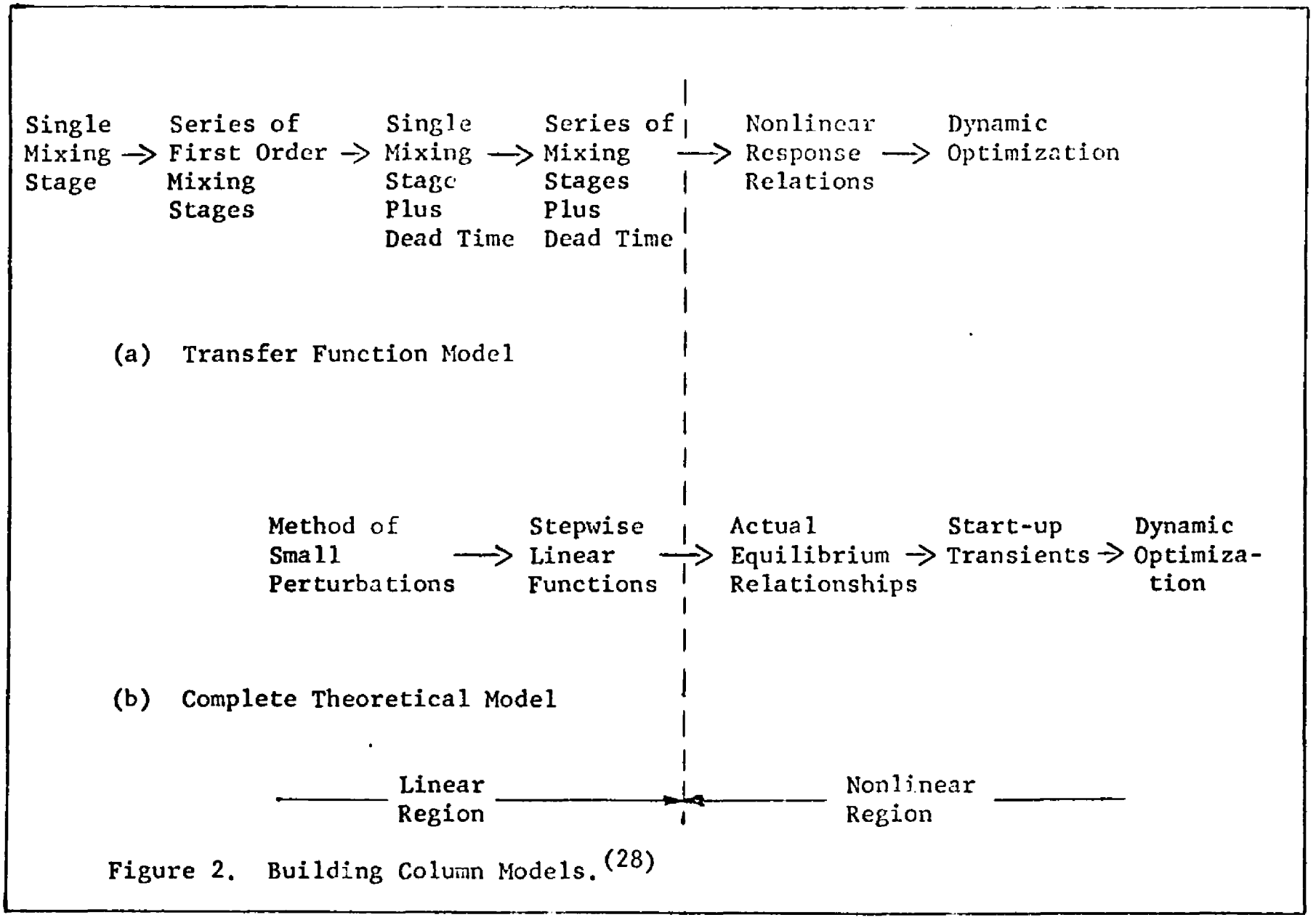


Figure 2. Building Column Models.[28]

The virtue of the transfer function is, as previously stated, that it so usefully represents experimental data. This requires some discussion. Of course, the more complex the assumed function is, the closer can be the simulated response to the actual response. The simpler transfer functions impose a penalty in their accuracy of representation, and the investigator must match his representation needs with the convenience of solution of the resulting equations. The total utility of the model is, then, the basic criterion to be applied during its conception.

With this general philosophy and concept of model approach, and in consideration of the actual experimental results achieved, it was decided that the basic transfer function model to be assumed in this study was a single exponential transfer stage with no dead time, i.e., a simple linear lag:

$$x(t) = x_o + (x_{\infty} - x_o)(1-e^{-t/T}) \qquad \text{(II-7)}$$

It was decided that on this basis the time constant of the transfer function could be correlated in terms of tray position and other column variables and parameters. This simple approach hopefully will allow future studies to linearize their distillation system, i.e., assume linear operating and equilibrium lines, and represent the entire system by a block diagram. This will allow the simple addition of various transients due to varying boundary compositions, flows, et cetera.

4. Column Interactions[3,7]

It would be unwise to leave the assumed column model so simply

stated without briefly mentioning column behavior and how this model might fit into the total column representation.

A very simple illustration of this can be seen in Figure 4(a). Here a measuring unit is sensing the value of x on tray n and adjusting the rate at which reflux is returned to the column. The question is, "How much of a change must be made in reflux rate to bring x_n to the desired value of x_n, which can be called x_{nd}?" The solution to the problem can be seen rather conveniently in Figure 4(b) where the problem is presented in block diagram form. Using block diagram algebra, x_n may be expressed:

$$x_n = [x_{nd} \cdot I(s) - x_n \cdot F(s)] \cdot [C(s) \cdot V(s) \cdot R(s)] \qquad \text{(II-8)}$$

or

$$x_n = \frac{I(s) \cdot C(s) \cdot V(s) \cdot R(s)}{1 + C(s) \cdot V(s) \cdot R(s) \cdot F(s)} \cdot x_{nd} \qquad \text{(II-9)}$$

where $I(s)$ = transfer function of input elements

$C(s)$ = transfer function of the controller

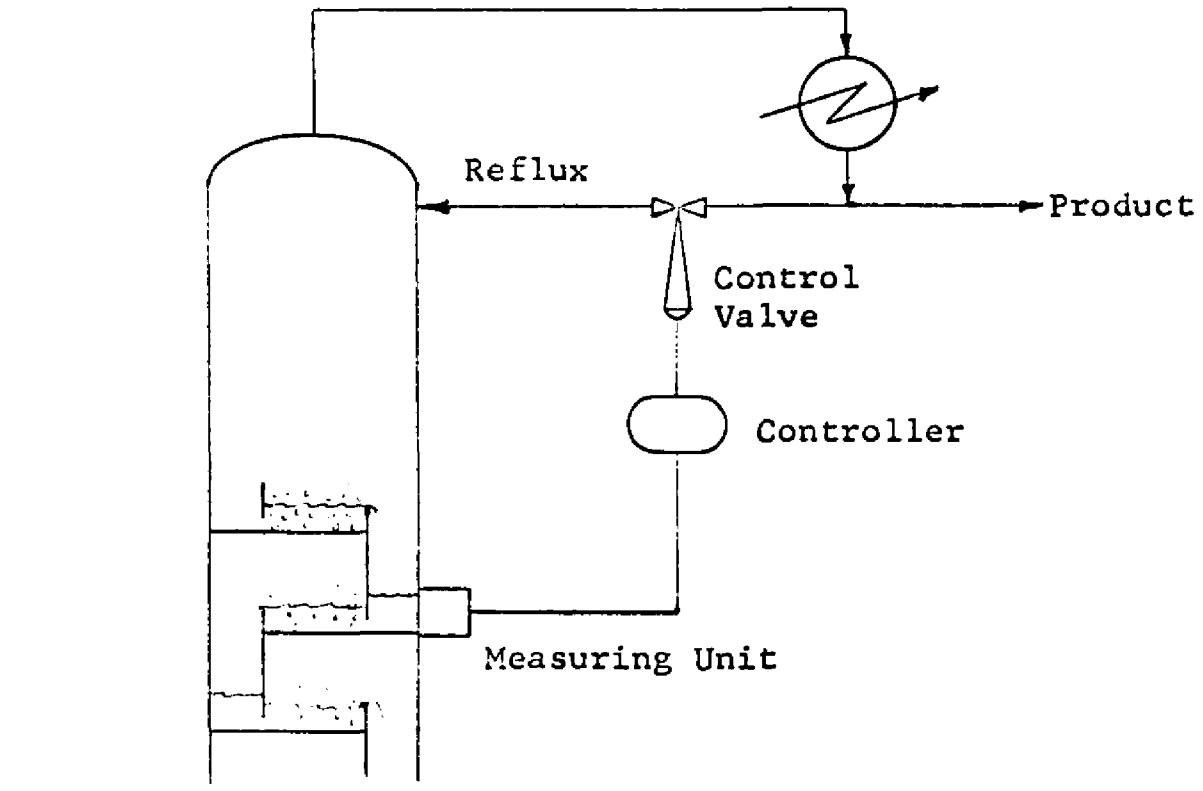
$V(s)$ = transfer function of the control valve

$R(s)$ = transfer function relating the change in x_n with a change in reflux flow rate

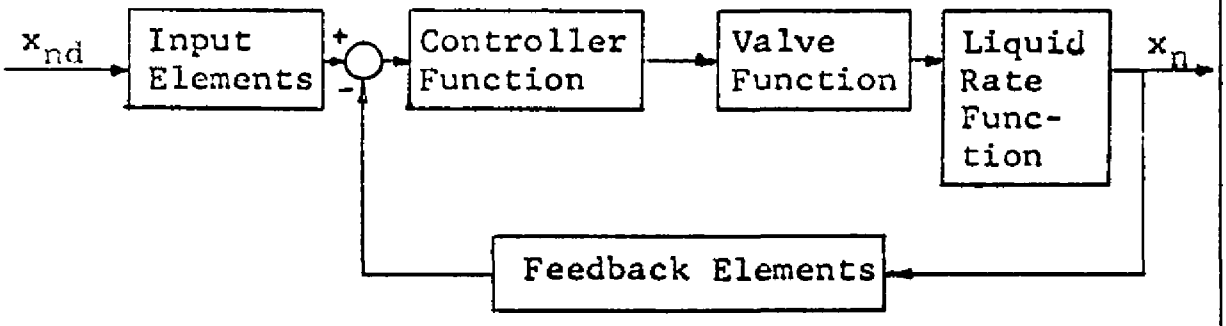
$F(s)$ = transfer function of the feed back elements

$I(s)$, $C(s)$, $V(s)$, and $F(s)$ are all characteristics of the equipment in use and can be obtained from the equipment itself. $R(s)$, of course, is the subject of this research. That this is a case of extreme importance is well documented by Williams[27] who points out that considering all types of upsets, the best all-round control of a distillation column is achieved by:

(a) Letting feed rate control boil-up, and



(a) Schematic



(b) Block Diagram

Figure 4. Reflux Flow Control. (3)

(b) Letting composition in the column control reflux.

Carrying this same concept to more general cases--within the restrictions of linearity--could yield the generalized diagram shown in Figure 5. Here a main loop is defined to control x_n based on the manipulation of some independent variable by the controller. The effects of variation in reflux flow rate are shown entering the loop as an external disturbance and exhibiting its influence on x_n. Likewise, other functions, as yet to be developed, can be shown as entering this same loop as external disturbances and the net result of their combined effect upon x_n is displayed.

Note that it can be misleading to look only at one particular section of a column because the interactions of the different sections are not evident. To keep this presentation in focus, the reader is referred to Figure 6. The primary reason for presenting this is to emphasize that a disturbance in either section of the column will be fed back through both sections. This will yield slower response for the column as a whole and will account, at least in part, for the larger time scales that are experienced in operating plate-type distillation column responses.

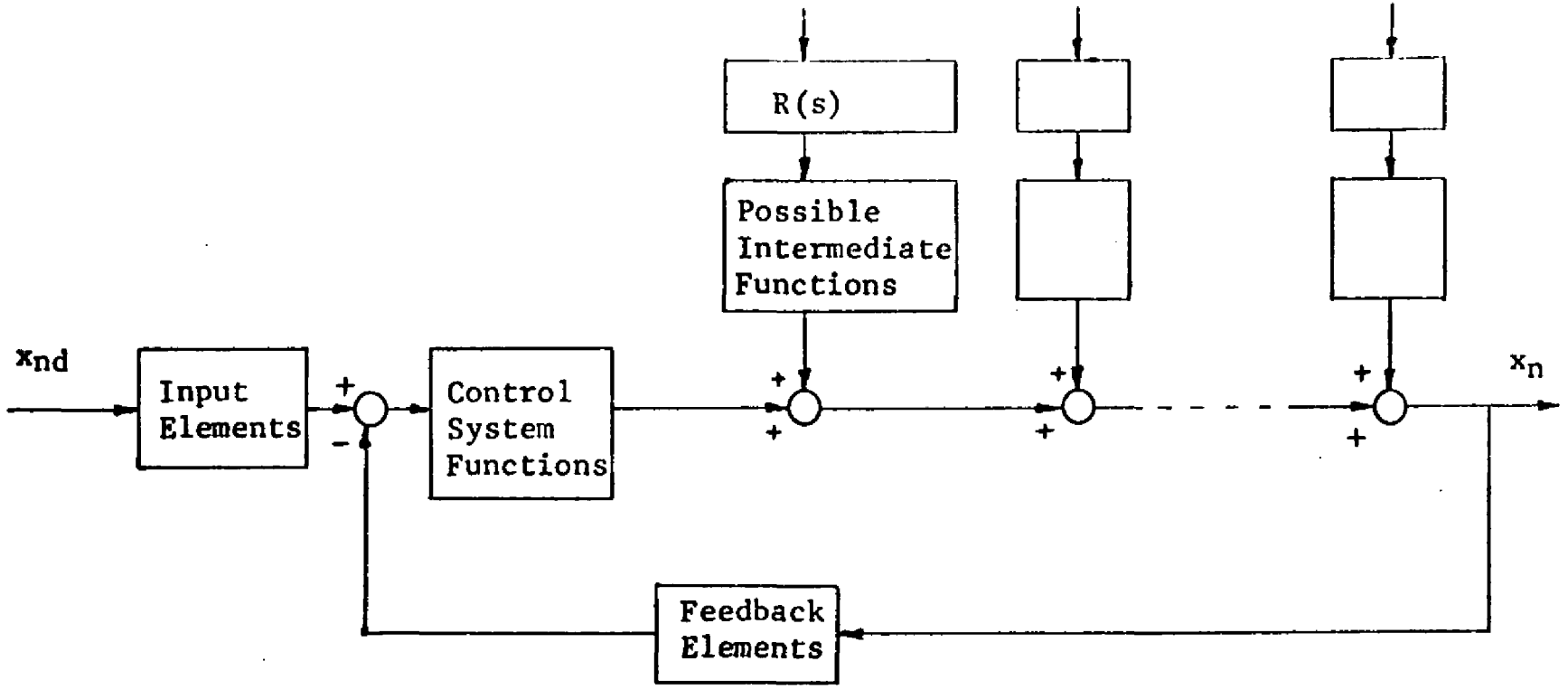
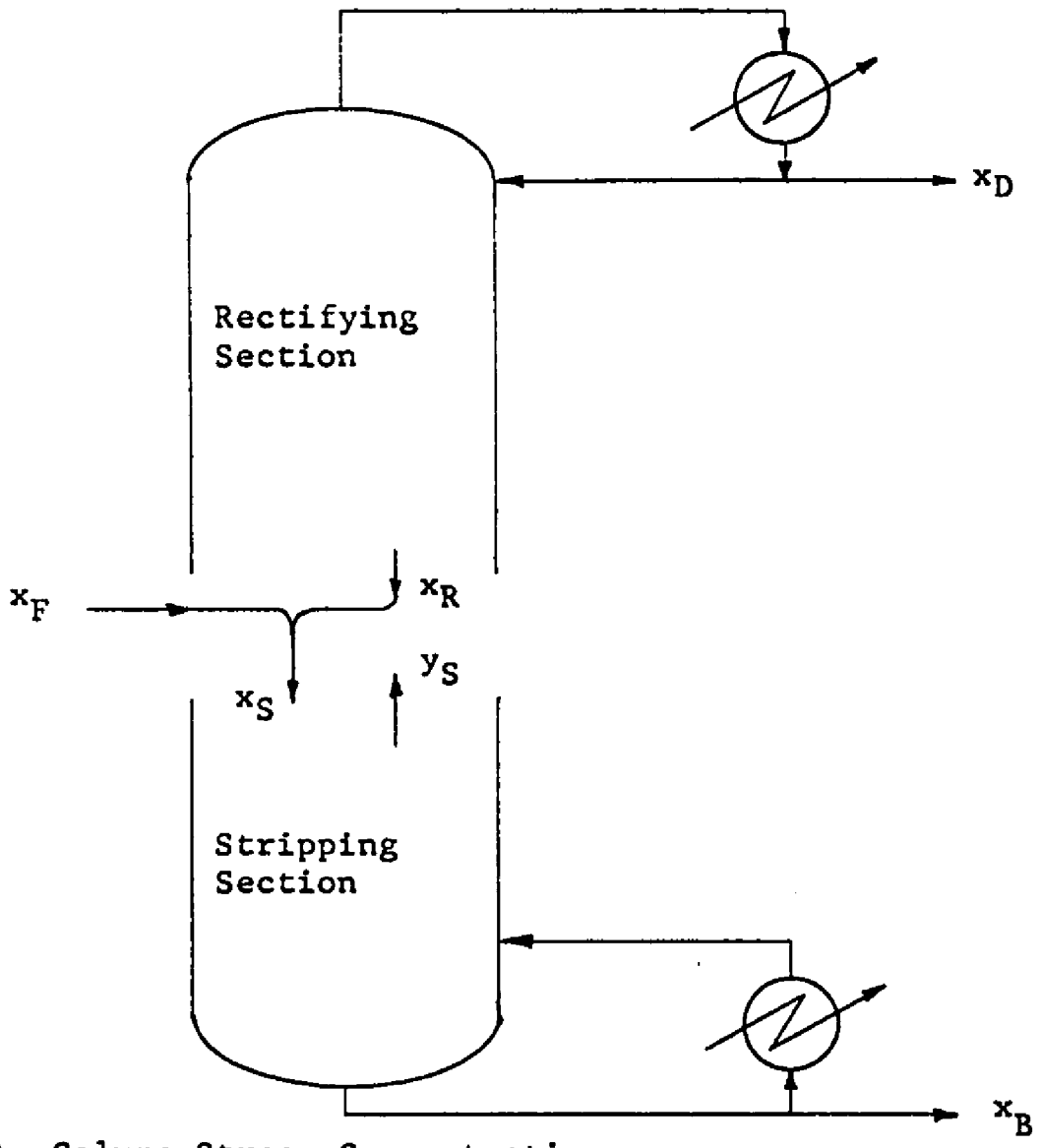


Figure 5. Generalized Block Diagram.



(a) Column Stream Concentrations

Change in x_F ⟶ Change in x_S ⟶ Change in x_B

Change in x_R ⟵ Change in y_S ⟶ Change in x_D

(b) Interactions of Changes

Figure 6. Interrelation of Column Streams.[7]

CHAPTER III

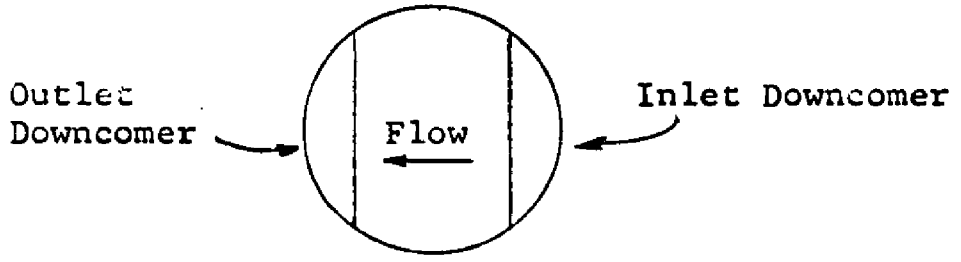
EXPERIMENTAL APPARATUS AND TECHNIQUES

1. Philosophy Underlying Apparatus Design[6,12]

In the conception of the experimental apparatus, it was initially necessary to decide the basic type of equipment to construct. The decision had to be made as to whether to build a column "model," i.e., a small column that would be geometrically similar in all respects to an industrial type column, only on a smaller scale, or whether to build a column "section," i.e., a slice of a larger column. Figure 7 illustrates the basic difference between the two concepts.

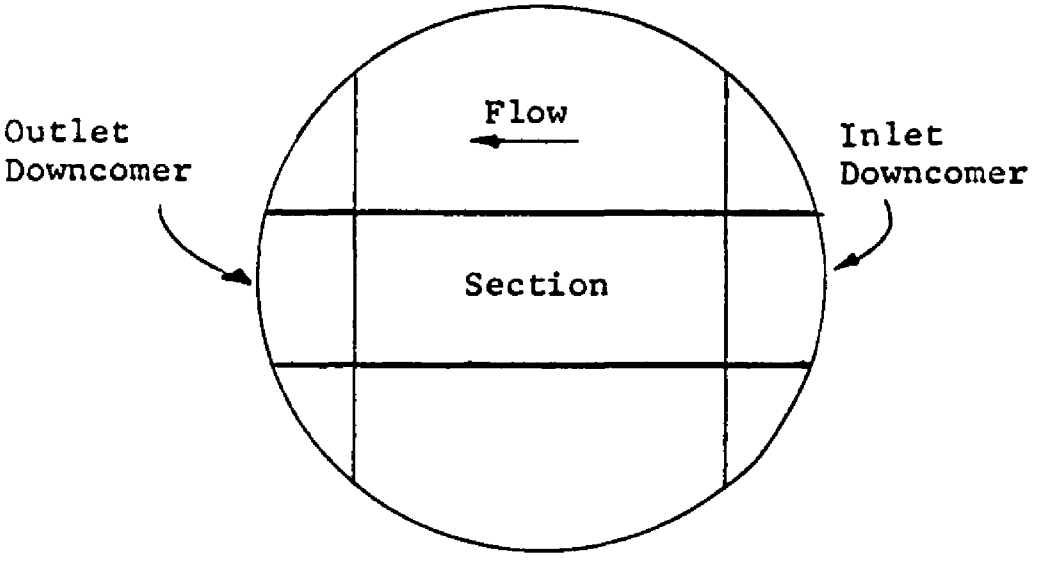
To determine which concept to use as a basis, it is desirable to look at the different classifications of column variables, i.e., geometric variables, physical property variables, and flow pattern variables. A typical dimensional analysis of this would yield dimensionless groups of the type: (1), geometric groups; (2), within-phase physical property groups; (3), between-phase physical property groups; and (4), flow pattern groups.

In work on a "model," groups (1), (2), and (3) may very conveniently be scaled-up, but groups of type (4) present a problem. The typical flow pattern groups are the Weber Number, Reynolds Number, Froude Number, and the L/V ratio. Only one of the first three may be maintained constant during scale-up; therefore, a functional relationship relating



Note geometric similarity to large column.

(a) Column Model



(b) Column Section

Figure 7. Comparison of a Column Model and a Column Section.

them must be found. To obtain independent variation of all three numbers it is necessary to employ different fluids; and this, in turn, varies the between-phase and within-phase physical property groups. Scale-up relationships become increasingly complex. An almost classic example of the problems inherent in this approach is found in the problems present in the design methods available for packed-type distillation columns.

Because of this problem and because of the very widespread use--almost exclusive use--of "model" type columns for distillation studies, it was decided to use a distillation column "section" for this study. It was hoped that the section concept would be convenient in dynamic studies such as this project and would also be very advantageous for other research projects in the realms of column design, tray efficiencies, et cetera.

The basic characteristic of a section which is necessary to comprehend is that it will produce, under identical operating conditions, the same change in the mixture under study as would occur in a larger column; but it will only produce this change in a smaller quantity of matter. All dimensions in the section are identical to those in the larger column except those which characterize the "slice" itself.

By the very nature of its basic conception, it is imperative that a section be so designed as to minimize wall effects. In a distillation column section, this implies that the width of the column section must be sufficiently large so that laminar wall layers will represent only a small portion of the column itself. For an 8 inch wide section, with vapor rates in their normal range for column operation, the typical laminar layer would comprise 1 to 3 per cent of the total section width, and this is certainly acceptable. It was finally decided

to adopt a column "section" with a cross sectional area of 8 inches by 20 inches.

It was also decided that an additional philosophy underlying the equipment design would be to incorporate as much basic flexibility as possible as far as mechanical configuration and column operation were concerned. This was justified on the basis of the needs of this particular research project, and also, on the needs of future projects which will use this basic equipment.

2. General Description of Apparatus

The column, as finally built and instrumented, is shown in the photographs on the following pages, Figures 8 through 13.

It consists of an 8 inch by 20 inch (rectangular cross section) tray support section that is 6 feet, 6 inches long. This tray support section is mounted on a bundle-in-column reboiler and is fitted overhead with a shell and tube type vapor condenser. The tray support section can be seen in Figure 9 as it is mounted in the apparatus. On the front side of the tray support section are three removable cover plates which open to a 6 foot by 20 inch portion of the tray support section.

The reboiler of the column actually consists of two separate tube bundles placed one above the other. Each bundle contains 26 tubes on a 1 1/2 inch triangular pitch in 3 rows of 9 each. They are 37 1/4 inches long, 16 BWG, steel tubes and are rolled into 3/8 inch tubesheets. This provides an outside tube area of 42.2 square feet for heat transfer purposes. The reboiler is supplied with 35 psi saturated steam which is admitted to the reboiler via a control valve (for use in closed loop situations).

Figure 8. Photograph of the Column Taken From the Right Rear Corner.

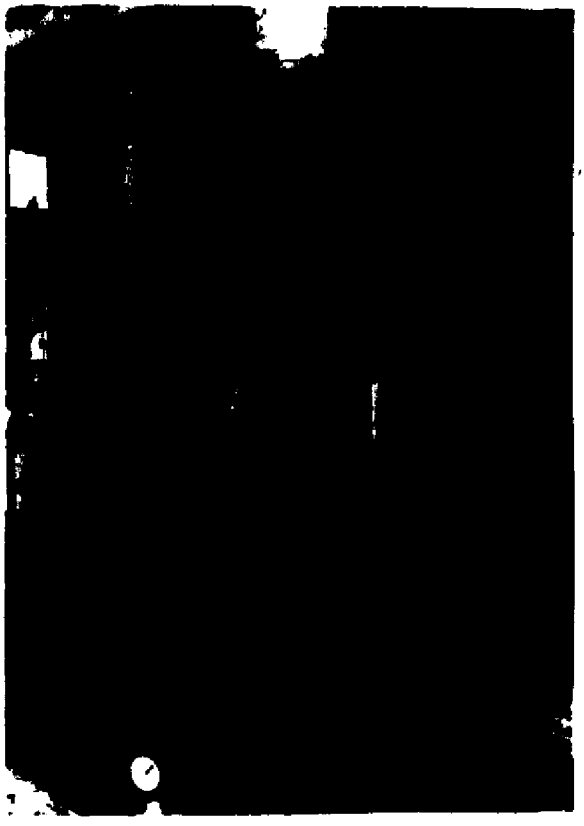


Figure 9. Photograph of the Column Taken From the Right Front Corner.

Figure 10. Photograph of Upper Portion of Column Taken From the Right Rear Corner.

Figure 11. Photograph of Column Tray Section With Sample Devices in Place.

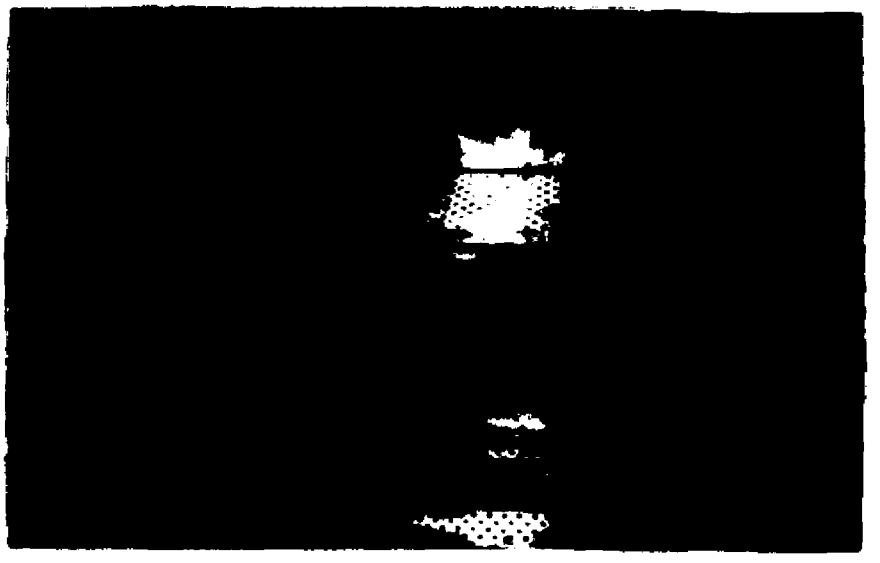


Figure 12. Photograph of an Individual Tray.

Figure 13. Photograph of the Entire Tray Section With Covers Removed.

The overhead condenser is a shell and tube type with vapor on the shell side entering at the top center and split-flowing along the length of the tubes. Three collection lines remove the condensate from the condenser. Cooling water is admitted to the tube side and makes four passes before leaving the unit. The tubes are 44 in number and are 1 inch, 16 BWG, steel and are 5 feet, 7 inches long giving a heat transfer area of 64.2 square feet. The condenser is fitted with a safety valve, a vent system, and an air padding system.

Condensate from the overhead condenser is led into a reflux system that allows it to be fed directly into the column via a rotameter or it can be fed into collection drums and, in this latter case, the reflux to the column is supplied through separate piping from an overhead supply drum. This entire reflux system is discussed more fully in Section 5 of this chapter.

In the area of instrumentation, the column is fitted with the following items:

(a) A twenty-four point Minneapolis-Honeywell Universal Electronik 15 Multipoint Temperature Recorder is installed on the unit. The sensing elements are copper-constantan thermocouples which are recorded via cyclic print on a 4 1/2 second interval. The present range of the instrument is 0 to 250° F and is accurate to $\pm$ 0.94° F. The present chart speed on the instrument is 30 inches per hour.

(b) Three Fisher and Porter rotameters are provided in the reflux system to meter liquid into the column. The three

separate instruments cover over-lapping ranges, and only the most appropriate one is used during a particular run. The ranges of the instruments for water of specific gravity of 1.0 are 0 to 0.620, 0 to 2.70, and 0 to 7.50 GPM.

(c) An orifice meter is installed in the cooling water line from the overhead condenser and is connected to a mercury manometer.

(d) Sight glasses are provided to measure liquid level in the reboiler, in both the reflux accumulator drum and the reflux supply drum, and in the tray downcomer from the middle tray of the tray section,

(e) A differential pressure gauge calibrated 0 to 8 inches of water is installed across an individual tray in the column.

(f) A rotameter is installed in the steam condensate line from the reboiler. This rotameter is preceded in the line by two annular pipe type heat exchangers to reduce flashing in the rotameter.

(g) Indicating pressure and temperature points are located as necessary over the entire unit.

(h) Sampling facilities are provided in the reboiler, in the reflux line, on each tray (several points on a tray in several cases), in the downcomer to the middle tray, in the vapor entering and leaving the middle tray (3 in each region), in both reflux drums, and in the vapor region above the reboiler liquid level.

(i) An observation window, complete with separate lighting, is provided on the middle tray of the column.

(j) A pneumatically controlled valve is installed in the steam supply line and may be by-passed or used with a vapor tension thermometer acting as sensing element for the controller.

Looking more closely at the tray support section, it has provisions to accommodate trays on 6 inch spacing, or any multiple thereof, over a 48 inch length. This means that trays can be spaced as follows:

9 on 6 inch spacing

5 on 12 inch spacing

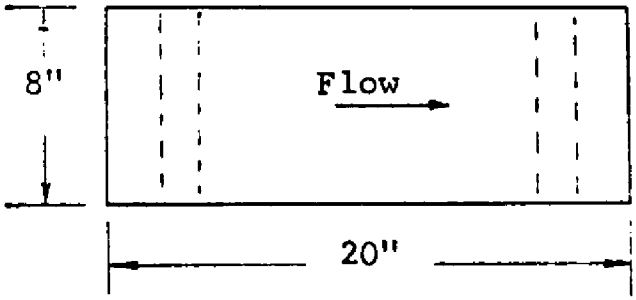
3 on 24 inch spacing

2 on 48 inch spacing

The individual tray decks are mounted on 1/2 inch bar stock frames, and provisions are made to remove the deck and substitute any type of tray deck desired. Overflow weir heights are adjustable as desired, and the clearance between the downcomer and the tray deck may be adjusted as desired. A typical tray layout and arrangement are shown in Figure 14 on the following page. The sketches in this Figure are representative of the configurations employed in the data runs of this project.

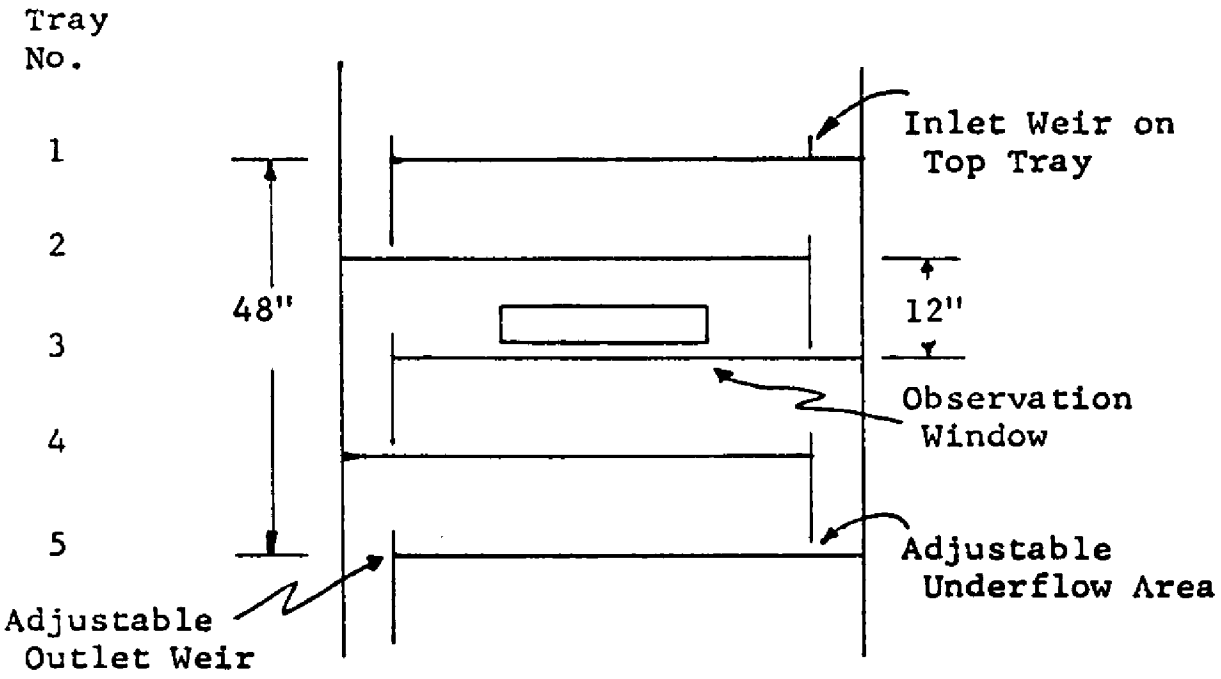
3. Specific Operating Configurations

The specific tray arrangement used in this study, as noted above, is based on the general arrangement shown in Figure 14. The tray itself was a sieve tray with 3/16 inch holes drilled on a 9/16 inch triangular pitch. The holes cover the 8 inch by 13 inch bubbling area to within 1/2 inch of the column walls with a total number of holes on each tray of 329. This provides a total hole area of 0.06299 square feet. On all runs there were five trays on 12 inch spacings.



Breakdown of flow path (left to right):
2" inlet downcomer
1.5" liquid calming zone
13" bubbling area
1.5" liquid calming zone
2" outlet downcomer

(a) Typical Tray Layout



(b) Typical Tray Spacing

Figure 14. Typical Tray Arrangement.

On all runs the inlet downcomer clearance was held constant at 3/4 inches; however, the outlet weir heights were varied according to the following schedule: on perturbation runs 101 to 111 the outlet weir height was set at 3 inches, and on perturbation runs 112 to 119 the outlet weir height was set at 1 1/2 inches. The tray spacing of 12 inches was not varied.

The column was operated on open loop control in all perturbation runs to avoid any feed back type of control or corrective action. Steam to the reboiler was supplied at a definite rate, and this rate was not varied at any time during the run. Both tube bundles in the reboiler were used on all runs.

The column was always operated with the condenser vented to the atmosphere to provide constant operating pressure.

4. Sampling Techniques and Arrangement

Liquid sampling was done with hypodermic syringes, an example of which may be seen in Figure 11. A hypodermic needle was cut in half and the two parts were soldered in the opposite sides of a brass plug cock. The entire assembly was screwed into the column wall, and whenever a liquid sample was desired, a syringe would be inserted into the needle female receptacle, the plug cock opened, the needle flushed, a sample withdrawn (2-4cc's), the plug cock closed, the syringe removed, and the sample transferred to a small receiving bottle. The syringe, in place in the plug cock, may be seen in Figure 11.

Vapor sampling was done via polyethylene sampling bags. A two-way plug cock was installed at vapor sample points, and into the inside receptacle of this cock was soldered a 1/16 inch piece of stainless

steel tubing which led to the region from which the sample was desired. A sample was taken by turning the two-way cock in one direction to flush the tubing and valve and then turning it in the reverse direction to fill the 6 inch by 12 inch polyethylene bag. When the bag was filled, the plug cock was turned off, and the bag was placed in a -15°C walk-in deep freeze. After condensation of the vapor had occurred, a person would go into the deep freeze and transfer the condensate into a receiving bottle. A vapor bag in the process of being filled may be seen in Figure 11.

Sample points on the unit were located according to the following general plan. On each tray a liquid sample point was located 1/2 inch above the tray deck and 1/2 inch on the inlet side of the first perforation in the tray deck. Also, on the top and middle trays there was a liquid sample point located 1/2 inch above the tray deck and 1/2 inch on the outlet side of the last perforation on the tray deck. On the middle tray an additional liquid point was located 1/2 inch above the tray deck and in the middle of the tray, and also, a point was provided in the inlet downcomer to the tray. Liquid sample points were provided in the reboiler and in the reflux line to the column. Three vapor sample points were provided 1/2 inch below the middle tray deck and three 1/2 inch below the tray deck above the middle tray. One was located at the center of the column and one on either side at a distance of 7 inches. Of course, on most runs only a small portion of these sample points were used.

After the samples were transferred to receiving bottles, the bottles were placed in a refrigerator to await analysis 1/2 to 2 1/2 hours later. When facilities were available for sample analysis, they

were transferred to a temperature bath which was maintained at a constant 19.6°C. This same bath provided constant temperature water for circulation to the refractometer which was used for all analytical work. This water to the refractometer was pumped via a 3 foot length of 3/8 inch tubing, and during the course of its transmission it would warm to 20°C. The refractometer was, therefore, maintained at a constant 20°C.

The refractometer itself was a Bausch & Lomb Precision Refractometer, Catalog Number 33-45-01-01, with a range of 1.20 to 1.51. The instrument can give accuracies in the order of 0.00003. A sodium Lab-Arc transformer was used in conjunction with the instrument, and a test piece was used periodically to verify the adjustment of the instrument.

For analyses the sample bottles were removed from the temperature bath, opened, an eye dropper of liquid removed, and the liquid was injected directly into the closed prism system. The instrument was read immediately. The refractometer scale reading was converted directly into sample properties, i.e., refractive index, composition, molecular weight, et cetera via a computer program. This was done primarily to avoid any errors in table look-ups, interpolation, or in transcribing results. The conversion was done by using polynomials which had been fitted to property data by least squares techniques, and in some cases, were as high as 6th order. The computer program for making this conversion is given, along with a typical output, in Appendix C.

5. Specific Operating Routines

The operating procedures employed were rather conveniently divided into two categories depending on the nature of the run. One

procedure was employed for those runs in which no dynamic studies were made at all, i.e., the column remained at steady state during the entire period of operation; and another procedure was employed when any type of liquid flow rate perturbation was to be imposed. Figure 15 will aid in the description of both of these procedures.

For steady-state runs the unit would be operated with the reflux supply tank and the reflux accumulator both completely by-passed. Valves V-1, V-3, and V-4 would be closed and valve V-2 would be open. Reflux would flow from the overhead condenser, via its drain line, down through valve V-2, through one of the three reflux rotameters, and into the column. For these studies the column was, therefore, operated at total reflux with virtually no outside hold-up.

For runs involving any type of perturbation, the column would be operated with valves V-1, V-3, and V-5 open, valves V-2 and V-4 closed, and the reflux pump in operation. The reflux accumulator was allowed to run "dry," and the reflux supply drum would be full to the overflow line. Reflux would flow from the condenser via its drain line, through valve V-1, into the reflux accumulator, be pumped to the reflux supply drum, overflow through valve V-3, and flow through one of the three reflux rotameters into the column. The column would be operated in this manner (total reflux) until steady state had been achieved in the unit. This normally required 1 1/2 to 3 hours and would be ascertained primarily by noting the variation of temperatures with time in the column. It might be pointed out here that the column was always operated in a composition range which would allow a maximum concentration difference across the tray section, and thus, large changes in

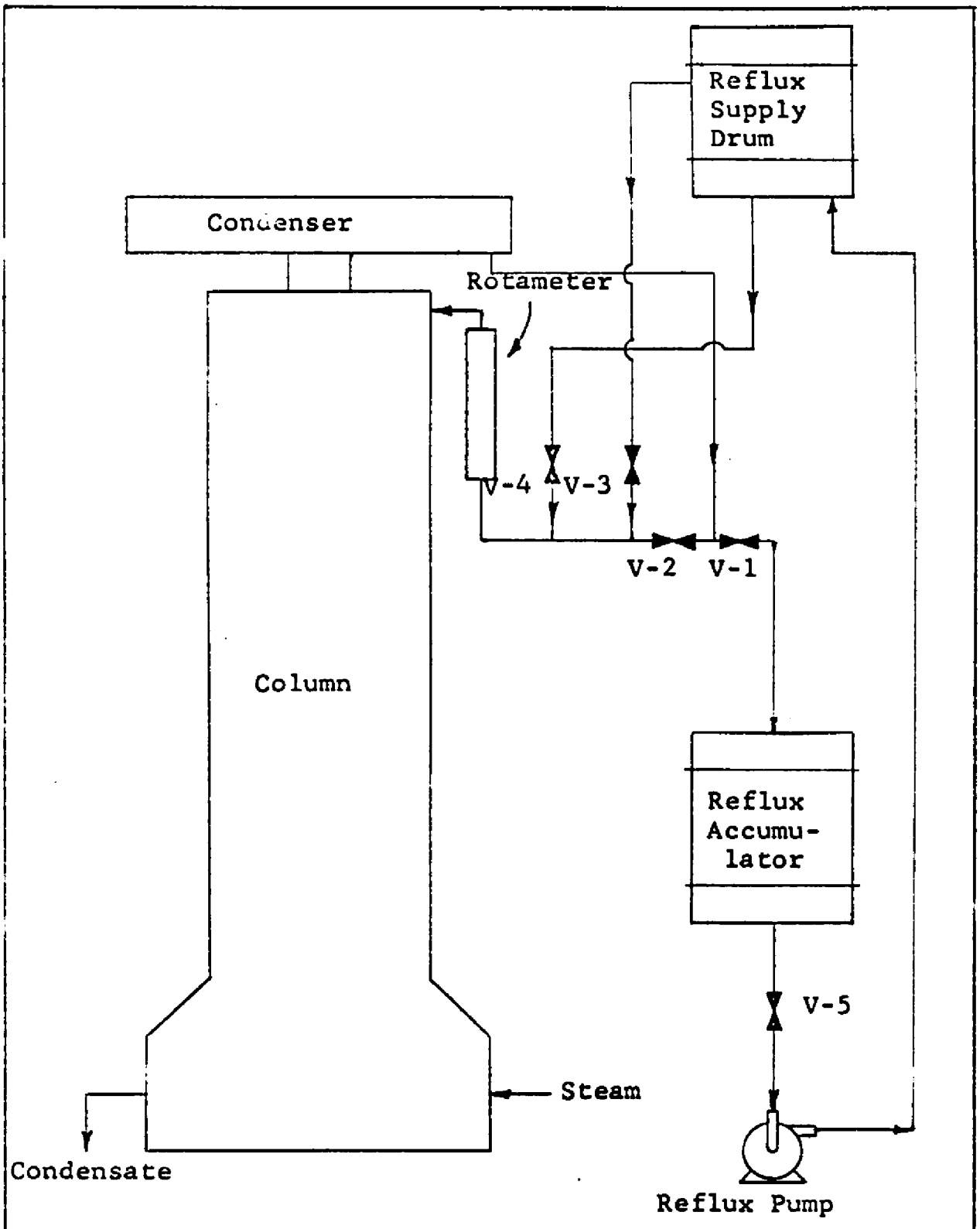


Figure 15. Reflux Piping Schematic Diagram.

temperature would be experienced. Thus operating temperatures provided a very excellent criteria of steady state within the column.

After steady state had been achieved on the unit, with the piping arrangement outlined above, the perturbation would be imposed in the following manner. At time zero, i.e., the beginning of the perturbation, valve V-4 would be opened, valve V-5 would be closed, and the reflux pump shut off. The reflux to the column would then be controlled by valve V-4 at any rate desired by using liquid from the reflux supply tank, and condensate from the overhead condenser would be collected in the reflux accumulator. This state of operation could be maintained for approximately 5 to 25 minutes depending on the reflux flow rate required. After the transient period had been experienced, the column would be returned to its original piping arrangement and a new period of "leveling out" at total reflux would be commenced.

During the imposition of the reflux flow rate perturbation, the steam supply to the column would be maintained constant, and therefore, no major changes in vapor rate were experienced. Since the reflux was being supplied from the same drum as before the start of the perturbation, there was no change in reflux composition or thermal condition. The reboiler was not pumped during any portion of the run, and there was, therefore, a change in both the total hold-up and the composition of the reboiler, but the total hold-up of the reboiler was so much greater than the hold-up of an individual tray (25 plus times greater) that this effect was secondary. The net result of this mode of operation was that the only major transient condition imposed on the column was the change in reflux flow rate.

An alternate method of imposing the flow rate change which proved to be very satisfactory was to provide reflux to the column during the steady state period via valve V-4 and keep valve V-3 closed. When this mode of operation was employed, it was only necessary to make an adjustment to valve V-4 to impose the flow rate perturbation.

CHAPTER IV

PRESENTATION OF RESULTS

1. Description of Runs Made

All of the studies conducted during this research project were made on the acetone-benzene binary mixture. The system was selected for the following reasons:

(a) The molal heats of vaporization of the two pure components are very nearly equal.

(b) The physical properties of the mixture are fairly readily available in the literature.

(c) The refractive indices of the pure components are widely separated, and hence, analysis via this means is very practical.

(d) This was one of the systems which was extensively studied by the American Institute of Chemical Engineers during their recently completed Tray Efficiency Research Project,[24] and much data on the behavior of the system in a distillation column was available from that source.

The runs were made on two different mechanical configurations as described in Section 4, Chapter III. The first group of runs were made using the basic tray arrangement described there and employing a 3 inch outlet weir height. In order to gain a basic insight into

column behavior and characteristics, a group of 7 runs was made in which the column remained entirely at steady state and the overall separating effectiveness or "tray efficiency" of the column was observed. In these runs the bulk of attention was given to observing and recording the separating effectiveness of the middle tray of the column because of the absence of end effects within the column, i.e., the sub-cooling of reflux at the top and the effect of the reboiler at the bottom.

Next it was decided to investigate the steady-state fluctuations which occurred in the column although no external transient conditions were imposed. To do this, the column was operated at so-called steady state for a period of time during which samples were withdrawn from a point at recorded time intervals. Three runs of this type were made at three different operating rates. These runs, just as those before, were all made under total reflux conditions.

With these 10 runs furnishing operating experience and column characteristics, the actual liquid rate perturbation runs were undertaken. Four runs were made, still with this 3 inch outlet weir height, in which a step increase change was made in the liquid reflux rate to the column. These increases were made at different vapor rates and ranged in magnitude from +7.1% to +82.8% increases in the initial or base rate. Next, 7 runs were made in which step decreases were made in the liquid reflux rate to the column. These ranged in magnitude, from -12.0% to -31.2% decreases in the initial or base rate and were, of course, made at different vapor rates.

At this point, the internal mechanical configuration of the column was altered by changing the outlet weir heights on all trays in

the column to 1.5 inches. With this new configuration, still using the acetone-benzene system, a series of runs similar to those for the 3 inch weirs was made.

Eight runs were made to determine the separating effectiveness of the column at different base operating rates. Next, the perturbation runs were undertaken with 5 step increases ranging in magnitude from +8.6% to + 21.5% of base rate and 3 step decreases made ranging in magnitude from -15.6% to -20.0% of the base rate.

In all the perturbation runs, samples were taken at timed intervals from the top tray, middle tray, bottom tray, the reboiler liquid, and the reflux to the column.

2. Results of Non-Perturbation Runs

Although the non-perturbation runs are, in a sense, incidental to the basic intent of this project, a brief space will be devoted here to the results achieved.

First, looking at the runs made to determine the separating effectiveness of the unit, to characterize the separation achieved across the middle tray, i.e., tray 3, the inlet liquid composition to tray 2 and to tray 4 were measured. As mentioned earlier, tray 3, the middle tray, was given special attention because it was free of "end effects" of the unit. The number of theoretical trays separating these two points was determined and, on this basis, an overall tray efficiency was determined by dividing the number of actual plates into the number of theoretical trays. The computer program for making this calculation is given in Appendix H. The results of this treatment are given in Table II where tray efficiency is plotted versus the vapor F factor.

TABLE II

TRAY SEPARATING EFFICIENCY

3 INCH OUTLET WEIRS

F FACTOR	EFFICIENCY
0.365	89.35
0.633	90.06
0.900	92.44
1.013	87.38
1.016	86.51
1.218	81.89
1.392	83.95
1.450	FLOODING

1.5 INCH OUTLET WEIRS

F FACTOR	EFFICIENCY
0.340	80.57
0.511	77.72
0.677	79.58
0.868	76.20
1.072	77.62
1.215	69.63
1.499	74.84
1.560	79.18
1.650	FLOODING

The F factor was chosen as the correlating factor because of its previously established usefulness.[24] It should also be mentioned that in all of these runs the overall concentration change across the column was occurring over a somewhat similar range; and therefore, the composition dependence of the separation, while not completely eliminated, was at least minimized.

Several items about the results are worthy of note. One, these values of tray efficiency are, in all cases, at least roughly equivalent to the efficiencies achieved by the American Institute of Chemical Engineers in their study.[24] This point adds credulity to the fact that the column was operating properly, and no wholesale by-passing of fluids was occurring within the column. Two, the results are, over a large range, relatively equal and this will contribute to an assumption of "constant tray efficiency" later in this Chapter.

The runs which were made to observe steady state fluctuations are worthy of note, also. Figures 16, 17, and 18 present data for the middle tray for each of the three runs made at different operating rates. Figure 16 is for the lowest rate and Figure 18 is for the highest rate. Each Figure gives two sets of data: one point is the inlet composition measured 1/2 inch before the liquid reaches the bubbling area, and one set of data is the outlet composition measured 1/2 inch past the bubbling zone. Note that Figure 16 employs a more exaggerated ordinate scale than Figures 17 and 18.

These three Figures give a clear picture of the degree of mixing on the tray with various operating rates. Figure 16 is at a relatively low rate, and the two sample points are rarely separated by more than

Figure 16. Steady State Fluctuations.

Tray Exit = o
Tray Entrance = ▲
F Factor = 0.571
L = V = 0.1814 mols/min

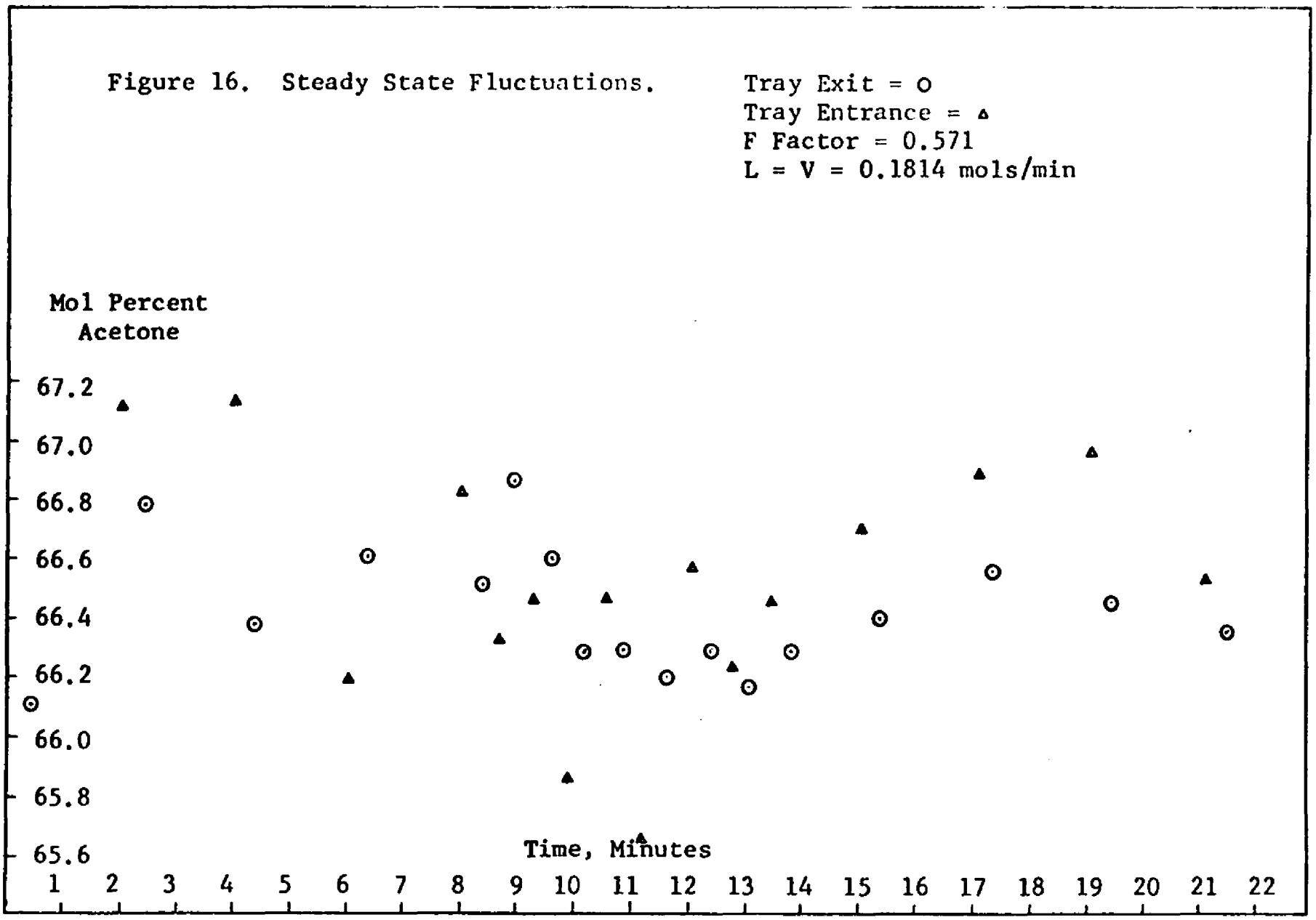


Figure 17. Steady State Fluctuations.

Tray Exit = o
Tray Entrance = ▲
F Factor = 1.017
L = V = 0.3215 mols/min

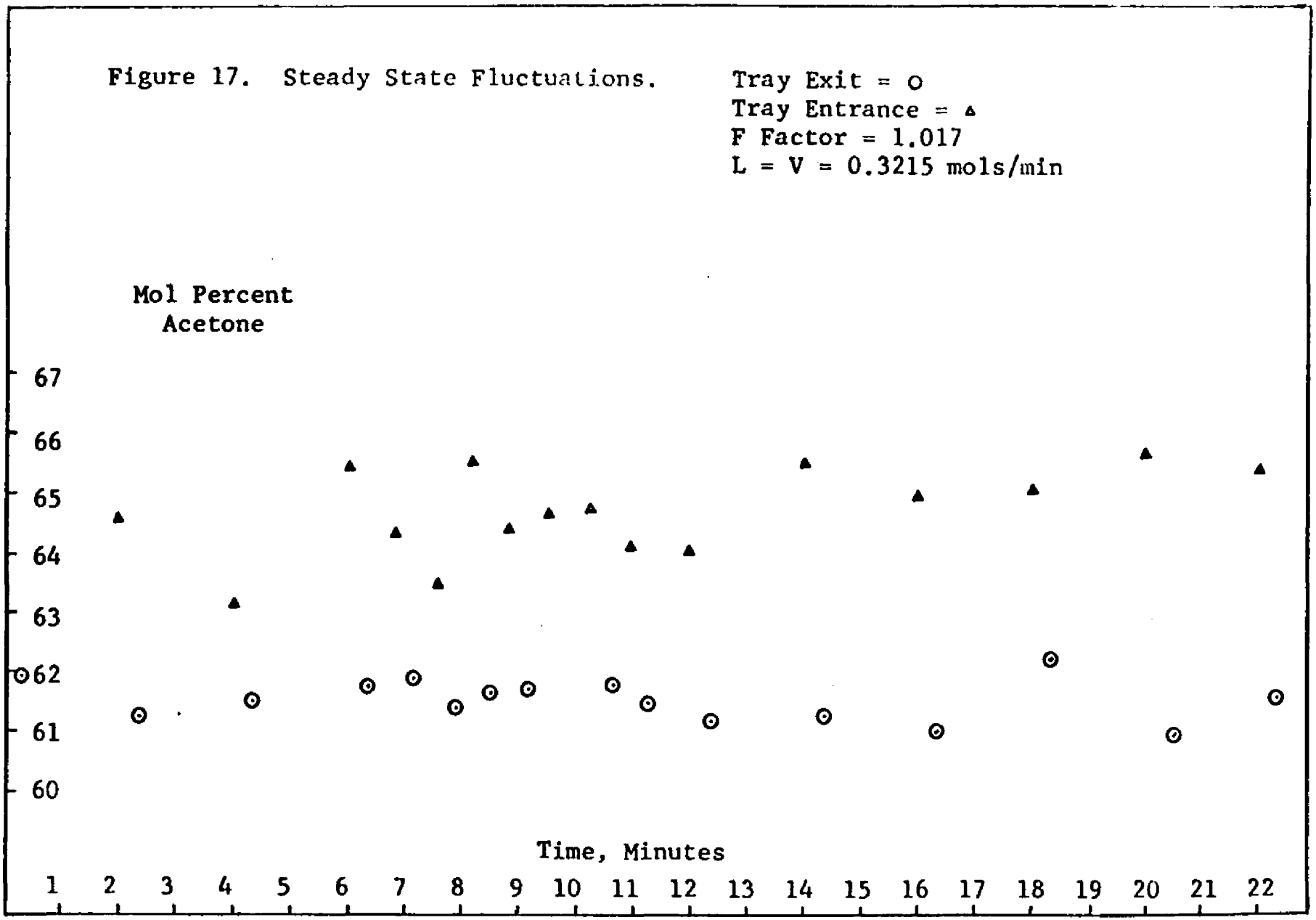
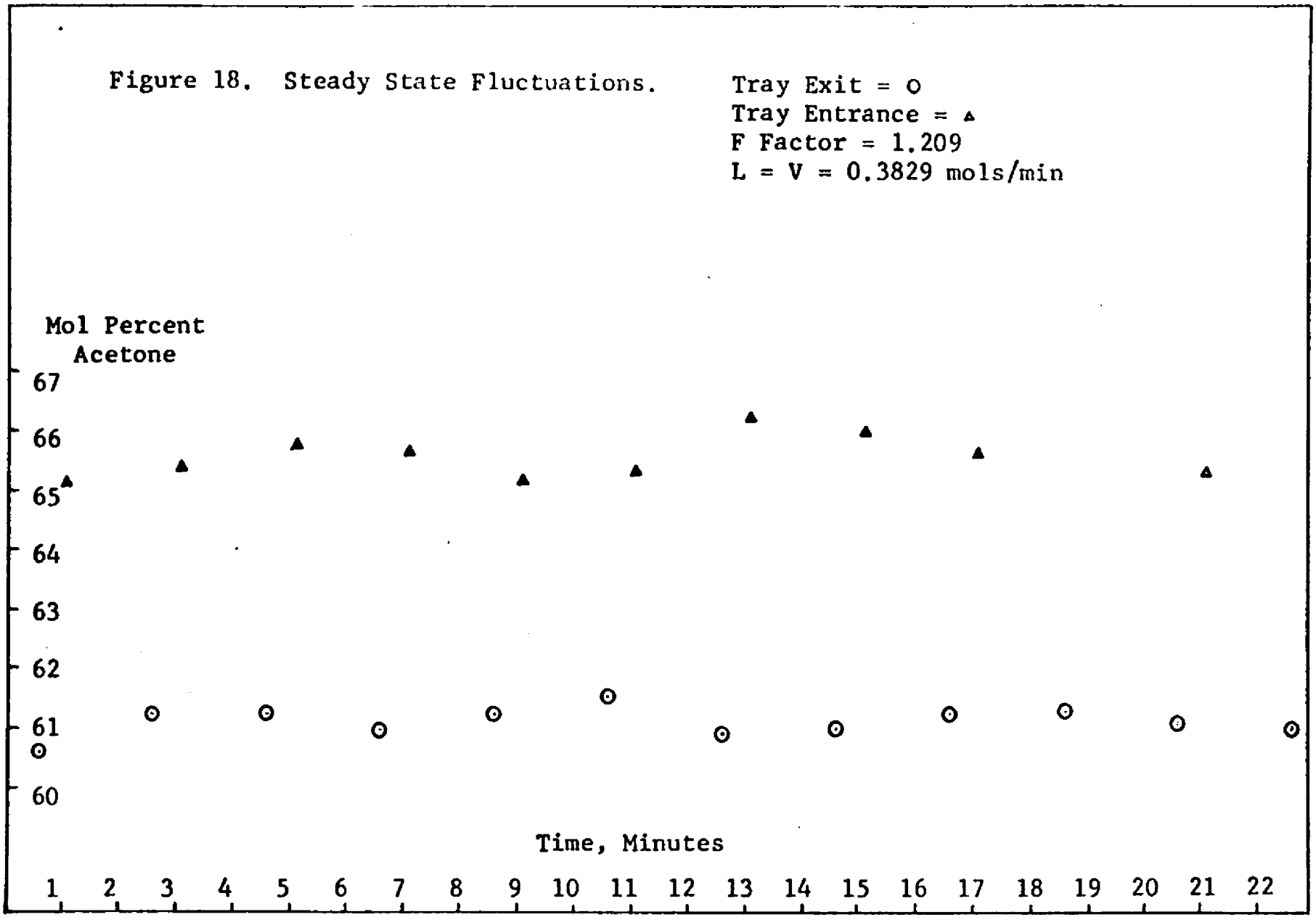


Figure 18. Steady State Fluctuations.

Tray Exit = o
Tray Entrance = ▲
F Factor = 1.209
L = V = 0.3829 mols/min



0.4 mol per cent, and at times the concentrations at the two points are nearly equal. This can be explained in terms of the longer residence time on the tray and the good mixing which results from the agitation of the vapor. Figure 17 is at a 77.23 per cent higher operating rate; and even though a much higher vapor rate gives a greater degree of agitation on the tray, the reduced residence time on the tray precludes the same degree of mixing as seen in Figure 16. These same observations are equally applicable to Figure 18 which is at a still higher operating rate (19.09% above Figure 17). These degree-of-mixing observations are useful in understanding some of the results achieved in the perturbation runs.

3. Treatment of Data From Perturbation Runs

The analysis of data from the perturbation runs was handled in a uniform manner for all runs. The determination of the physical properties of every sample was handled as described in Section 4, Chapter 3, and using the computer program given in Appendix C. The resulting sample "mol per cent acetone" data were plotted versus time in order to characterize tray behavior during the transient period following a liquid rate perturbation. This was done for the top, middle, and bottom trays, for the reflux, and for the reboiler for every run. The data obtained for the transient behavior of tray composition, which is the data of prime interest to this project, is given completely in Appendix B, Part 3 under the heading of "Experimental Observations." A typical plot of one of these sets of data is given in Figure 19. Note that the shape of the data curve in Figure 19 appears to be a

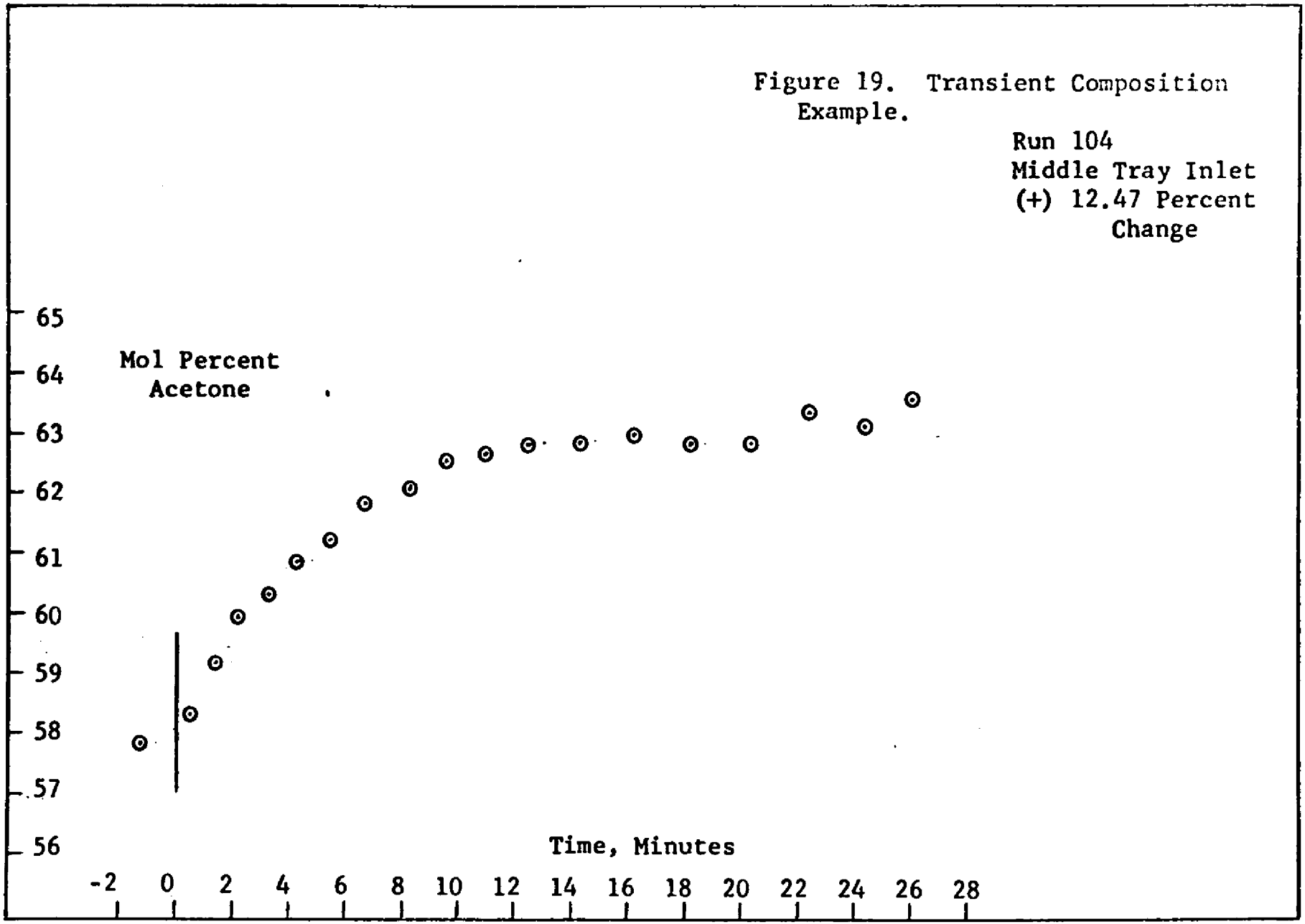


Figure 19. Transient Composition Example.

strong re-inforcement of the single exponential transfer stage model because of its similarity to the equation:

$$x(t) = x_o + (x_{\infty} - x_o)(1 - e^{-t/T}) \qquad \text{(II-7)}$$

Next it was necessary to obtain numerical values for all of the parameters which characterize column operating behavior. The computer program presented in Appendix D was written for this purpose. A typical print-out for the program is given in Appendix D, Part 3 and this, in itself, stands as a list of the parameters which were evaluated from operating data. Several items of note must be mentioned in connection with this program: one, it makes the assumption of constant molal overflow within the column; two, tray deck hold-ups are calculated by using the method proposed by the American Institute of Chemical Engineers[24] and are expressed in terms of lb mols for the top, middle, and bottom trays separately; three, the Eld jetting equation[8] was experimentally verified as being an accurate indication of column flooding and is calculated and used as such in the program; four, the program was used to evaluate column parameters for every run at several different times; and five, the representation of physical properties in the program is done by polynomials which were fitted to experimental data by least squares techniques. The program was used very successfully to quickly convert column operating data into the parameters needed to describe the column operating conditions and was very useful in the evaluation of data.

At this point in the treatment of the experimental data it was necessary to find some means of expressing the data in terms of the

basic model assumed, i.e., a simple linear lag:

$$x(t) = x_o + (x_{\infty} - x_o)(1 - e^{-t/T}) \qquad \text{(IV-1)}$$

The three variables in this expression are x_o, x_{∞}, and T, and the question naturally arose of how to objectively evaluate their respective values. The first variable, x_o, was easily determined from the experimental data on hand, and on the basis of this evidence, was evaluated in a like manner for every tray on every run.

The evaluation of x_{∞} and T is not so simple. The initial approach to the problem was to fit the experimentally determined data to the two-parameter equation resulting from equation (IV-1) where x_o is specified. This was done by least squares techniques, and the computer program for its accomplishment is given in Appendix E.

The computer program outlined in Appendix E worked very well in evaluating x_{∞} and T for equation (IV-1) for all cases in which there was an increase in the liquid flow rate, and this is the manner in which all such data was evaluated.

For runs in which there was a decrease in reflux flow rate there was an attendant decrease in tray composition, and for runs in which there was an increase in reflux flow rate there was an increase in tray composition. That this is correct may be seen in the McCabe-Thiele type plot of Figure 20. Some cases in which there was a decrease in reflux flow rate presented a problem in the use of the computer program given in Appendix E although it worked very well in most cases and yielded data similar in nature to that for flow rate increases. In a few cases, however, the large decrease cut the basic liquid rate so low that large time constants were experienced, and the run could not be maintained for

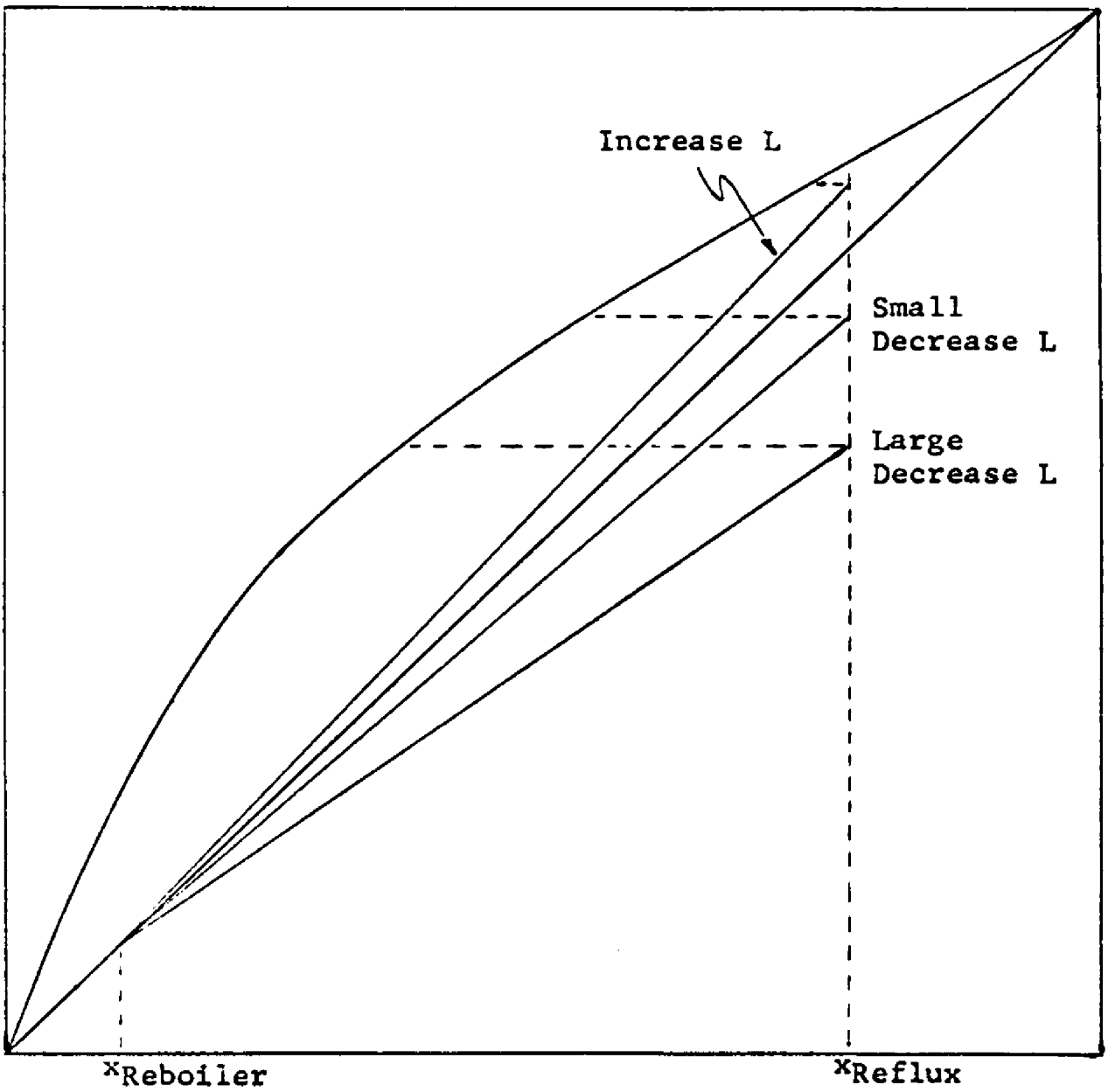


Figure 20. Typical Operating Lines for Increase and Decrease in Liquid Rate.

sufficient time to allow tray composition a chance to level out and approach a value of x_{ss}. These large time constants, coupled with the large changes in tray composition experienced for liquid rate decreases (see Figure 20), made the use of the Appendix E computer program of dubious worth.

In order to circumvent the problem outlined above, it was decided to use calculated values of x_{ss}, and two methods were devised to calculate x_{ss}. Both means are really modifications of the same basic method, but both separate routines are given in the Appendices. The first method involved calculating for steady state conditions the number of theoretical stages separating the reflux composition and every tray composition in the column. It was then assumed that during the perturbation period the number of stages separating these points remained the same, i.e., the overall tray efficiency remained the same. The calculation was then re-done with a new operating line employing the new slope L/V and passing through the point on the y = x line for the steady state reboiler composition. The use of this operating line implies that the composition of the reboiler does not change. Upon reflection and observation it turns out that this is not a bad assumption for the portion of the transient behavior which is of most importance, i.e., the initial period. The hold-up of the reboiler is so much greater than the total hold-up of a tray--at least twenty-five plus times greater--that this is initially a valid assumption. The computer program which employs this means of calculation is given in Appendix F.

A slight modification of this overall approach in the above method of calculation of x_{ss} was developed in which the program in Appendix F

was extended to calculate a new reboiler composition. This gave a new operating line, and this was repeated again and again till the calculated reboiler composition agreed with the assumed reboiler composition. The computer program for this method of attack is given in Appendix G.

In comparing the two means of calculating x_{∞}, use was made of the experimental data available for runs where a value of x_{∞} was approached, and on this basis it was clear that the assumption of a fixed reboiler composition was better for the initial transient data of interest to this project.

With the value of x_{∞} determined above, and the value of x_o obtained directly from the experimental data, it was a simple matter to determine the value of the time constant T; because from equation (IV-1), when $t = T$ the total change to be experienced, i.e., $(x_{\infty} - x_o)$ will be $(1 - 1/e)$ or 63.21 per cent complete. Knowing this, it is a simple matter to pick off a value of $t = T$ where 63.21 per cent of the value of $(x_{\infty} - x_o)$ has occurred. In order to be consistent and objective in the treatment of the experimental data, this was done for all runs in which a decrease was made in the liquid reflux rate to the column.

4. Results and Correlation of Time Constant Evaluations

Using the techniques outlined above, the time constants were evaluated for every perturbation run for bottom, middle, and top tray separately. The resulting data are presented, classified according to outlet weir height, in Table III for the bottom tray, Table IV for the middle tray, and in Table V for the top tray. In attempting to correlate these time constants, it was felt advantageous to attempt to correlate them in terms of the natural time constant for a perfectly mixed tank or

TABLE III

BOTTOM TRAY TIME CONSTANT DATA

3 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
101	0.373	.213	4.00	.105	.141	8.083	6.048
102	0.451	.179	4.86	.100	.135	8.659	6.429
103	0.504	.102	5.25	.094	.128	5.707	4.204
104	0.449	.158	5.76	.102	.138	8.966	6.614
105	0.468	.123	7.28	.096	.132	9.328	6.818
106	0.607	.151	8.00	.094	.129	12.886	9.369
107	0.775	.195	5.04	.087	.122	11.299	8.050
108	0.944	.252	2.41	.083	.121	7.250	4.988
109	1.010	.222	2.71	.080	.116	7.512	5.189
110	1.254	.422	2.38	.078	.122	12.777	8.243
111	1.281	.338	3.49	.075	.115	15.661	10.220

1.5 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
112	0.542	.201	3.70	.082	.104	9.070	7.114
113	0.547	.181	3.44	.080	.102	7.764	6.081
114	0.609	.144	3.32	.077	.099	6.161	4.797
115	1.042	.389	2.30	.070	.097	12.789	9.158
116	1.056	.354	2.32	.068	.095	12.052	8.928
117	1.102	.282	2.75	.065	.092	11.952	8.426

TABLE IV

MIDDLE TRAY TIME CONSTANT DATA

3 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
101	0.373	.213	4.17	.111	.148	7.992	5.979
102	0.451	.179	4.70	.107	.145	7.831	5.815
103	0.504	.102	4.86	.098	.134	5.047	3.716
104	0.449	.158	5.06	.108	.147	7.413	5.468
105	0.468	.123	6.50	.103	.141	7.811	5.712
106	0.607	.151	6.35	.100	.138	9.569	6.959
107	0.775	.195	3.85	.091	.128	8.217	5.853
108	0.944	.252	3.23	.089	.129	9.149	6.293
109	1.010	.222	3.15	.083	.121	8.356	5.768
110	1.254	.422	2.20	.083	.131	11.079	7.095
111	1.281	.338	3.23	.080	.123	13.645	8.897

1.5 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
112	0.542	.201	2.80	.087	.111	6.433	5.042
114	0.609	.144	4.07	.081	.104	7.201	5.605
115	1.042	.389	1.96	.074	.104	10.261	7.345
116	1.056	.354	2.02	.073	.102	9.796	6.986
117	1.102	.282	2.45	.069	.098	10.016	7.063
118	1.273	.442	2.02	.067	.099	13.403	9.071

TABLE V

TOP TRAY TIME CONSTANT DATA

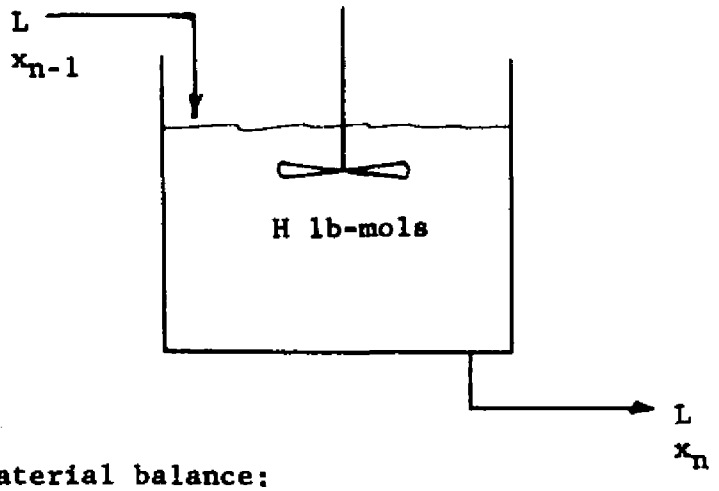
3 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
102	0.451	.179	3.88	.111	.150	6.265	4.653
103	0.504	.102	4.28	.106	.144	4.135	3.047
104	0.449	.158	4.62	.111	.150	6.604	4.872
105	0.468	.123	6.92	.109	.149	7.866	5.754
106	0.607	.151	8.21	.105	.144	11.877	8.636
107	0.775	.195	2.95	.097	.137	5.891	4.194
108	0.964	.252	2.55	.093	.136	6.861	4.716
109	1.010	.222	2.33	.089	.129	5.787	3.994
110	1.254	.422	2.13	.086	.133	10.491	6.771
111	1.281	.338	3.42	.083	.127	13.910	9.074

1.5 INCH WEIRS

RUN NO.	F FACTOR	LIQUID RATE	TAU	DECK HOLD-UP	TOTAL HOLD-UP	(TAU)(L)/ (DECK HU)	(TAU)(L)/ (TOTAL HU)
112	0.542	.201	2.85	.091	.116	6.290	4.936
113	0.547	.181	3.00	.093	.115	6.036	4.726
114	0.609	.144	3.07	.086	.111	5.106	3.970
115	1.042	.389	1.72	.076	.107	8.753	6.266
116	1.056	.354	2.07	.075	.105	9.765	6.966
117	1.102	.282	2.47	.072	.102	9.638	6.794

stage. This can be determined as follows:



By material balance:

$$Lx_{n-1} - Lx_n = \frac{d(x_n H)}{dt} \qquad \text{(IV-2)}$$

Assuming H constant:

$$Lx_{n-1} - Lx_n = HDx_n$$

or

$$x_{n-1} = \left(\frac{HD}{L} + 1\right) x_n \qquad \text{(IV-3)}$$

Therefore, $\frac{H}{L}$ is the natural time constant of the tank.

In order to relate the two time constants, i.e., the tray time constant and the natural one proposed above, it was decided to divide one by the other to form a dimensionless number of the form (TL/H). The L to use would be the perturbed liquid rate in the column, and the H would be the tray hold-up. The question of correct tray hold-up to use raised the problem of whether or not to include the downcomer hold-up. Initially it was decided to calculate the value of the dimensionless number by using both total tray and deck hold-up separately and let the results determine which method is more correct. The use of

total tray hold-up appears on the surface to be useful since it is impossible to disregard the dead time caused by downcomer hold-up. The results of these dimensionless number calculations are also given in Tables III, IV, and V.

The question naturally arises as to which, if any, of the system's physical properties should be included in this dimensionless number to characterize the time constant of a distillation column tray. It seems intuitively apparent that some of the physical properties should enter into the formulation of the relationship. One possible relationship comes to light if the following case is considered. The material balance for a perfectly mixed transfer stage would be as follows:

$$L_{n-1}x_{n-1} - L_nx_n + V_{n+1}y_{n+1} - V_ny_n = \frac{d(Hx_n + hy_n)}{dt} \qquad \text{(IV-4)}$$

Assume: $h = 0$

H = constant

$L_{n-1} = L_n = L$

$V_{n+1} = V_n = V^o$

$y_n = mx_n$

$y_{n+1} = mx_{n+1}$

(IV-4) becomes:

$$Lx_{n-1} + V^oy_{n+1} = (L + V^om + HD)x_n \qquad \text{(IV-5)}$$

Assume further: m = constant in region of interest

V^o/L = constant, i.e., small perturbations

By re-arrangement (IV-5) becomes:

$$\frac{x_{n-1}}{m} + \frac{V^o}{L} x_{n+1} = \left(\frac{1}{m} + \frac{V^o}{L} + \frac{HD}{mL}\right)x \qquad \text{(IV-6)}$$

Since the first two terms on the right hand side are constants, the natural time constant is proportional to $\frac{H}{mL}$.

While the simplifying assumptions made may be outside the range of a workable situation, the results at least point out a possible property to include in the correlation of a time constant. This inclusion of physical properties is not explicitly carried out in this paper, but it is pointed out here as a possible area for further consideration when other physical systems are included in future work.

Two observations about these (TL/H) values are noteworthy. First, as column loading increases and back-mixing decreases, the well-mixed stage idea becomes less valid and the value of (TL/H) becomes greater. This observation is made on the basis of Figures 15, 16, and 17 and is to be expected. Second, (TL/H) values in an operating column would be expected to be higher than these because of the "feedback" effects noted in Figure 6.

To correlate the time constants for this particular study, it was decided to plot the time constants obtained (Tables III, IV, and V) versus the vapor F factor, i.e., the superficial vapor velocity times the square root of the vapor density in lbs/ft^3. The F factor was chosen as the correlating factor because it was felt that the time constant must certainly be dependent in some way on the vapor loading of the column. The F factor was chosen instead of the simple vapor rate because of its previously determined worth as a vapor correlating factor.[24]

The data of the resultant plots were fit by least squares techniques to both first and second order equations; and without exception, the first order fit was just as good as the second order fit. The first order resultant equations are presented in Table VI. Note here that the equations were fitted for the individual tray and weir heights and for various combinations. They are also plotted both in terms of total tray hold-up and tray deck hold-up. The equations represented by these data are plotted in Figures 21 through 25.

5. Comparison of Predicted Results With Experimental Results

The ultimate criteria of the worth of any means of correlating the time constants is, of course, the ability of the correlation to predict the system's behavior. To this end the correlations were used to predict time constants for the perturbation runs made, and by using these time constants, predict the transient composition of the system within the column. Once the value of the time constant had been determined, the computer program in Appendix B was used to make the comparison of experimental to predicted results. Here, as before, the value of x_o was the one set by the experimental data, and the value of x_{∞} was the one predicted by the experimental data wherever possible. In cases where the experimental data did not predict a clear value for x_{∞}, the value predicted by the program in Appendix F was used.

Included with Appendix B are the computer results for the case in which the time constant was the one predicted for the individual weir and the individual tray. Figures 21 and 23 were used. For each experimental data point the observed mol per cent, time of observation, and predicted mol per cent are given. As an error indication the difference

TABLE VI

RESULTS OF A LEAST SQUARES FIT OF TIME CONSTANT DATA TO A LINEAR EQUATION

PART A - TOTAL TRAY HOLD-UP DATA

DESCRIPTION	SLOPE	INTERCEPT
BOTTOM TRAY, 3 INCH WEIRS	2.2598	5.2573
MIDDLE TRAY, 3 INCH WEIRS	2.5215	4.2809
TOP TRAY, 3 INCH WEIRS	2.5300	3.6120
BOTTOM TRAY, 1.5 INCH WEIRS	5.3299	3.0663
MIDDLE TRAY, 1.5 INCH WEIRS	4.5978	2.5423
TOP TRAY, 1.5 INCH WEIRS	4.1331	2.2359
BOTTOM TRAY, BOTH WEIRS	3.0880	4.7345
MIDDLE TRAY, BOTH WEIRS	3.1377	3.8561
TOP TRAY, BOTH WEIRS	2.9698	3.2393
ALL TRAYS, BOTH WEIRS	2.9967	4.0131

PART B - DECK HOLD-UP DATA

DESCRIPTION	SLOPE	INTERCEPT
BOTTOM TRAY, 3 INCH WEIRS	4.9007	6.2139
MIDDLE TRAY, 3 INCH WEIRS	5.1250	4.9557
TOP TRAY, 3 INCH WEIRS	5.0442	4.0629
BOTTOM TRAY, 1.5 INCH WEIRS	8.7512	2.8207
MIDDLE TRAY, 1.5 INCH WEIRS	8.1069	1.9194
TOP TRAY, 1.5 INCH WEIRS	6.9833	1.8972
BOTTOM TRAY, BOTH WEIRS	5.8106	5.4291
MIDDLE TRAY, BOTH WEIRS	5.7650	4.3533
TOP TRAY, BOTH WEIRS	5.5182	3.4699
ALL TRAYS, BOTH WEIRS	5.6075	4.5100

Figure 21. Time Constant Factor, 3 Inch Weirs, Total Tray Hold-Up.

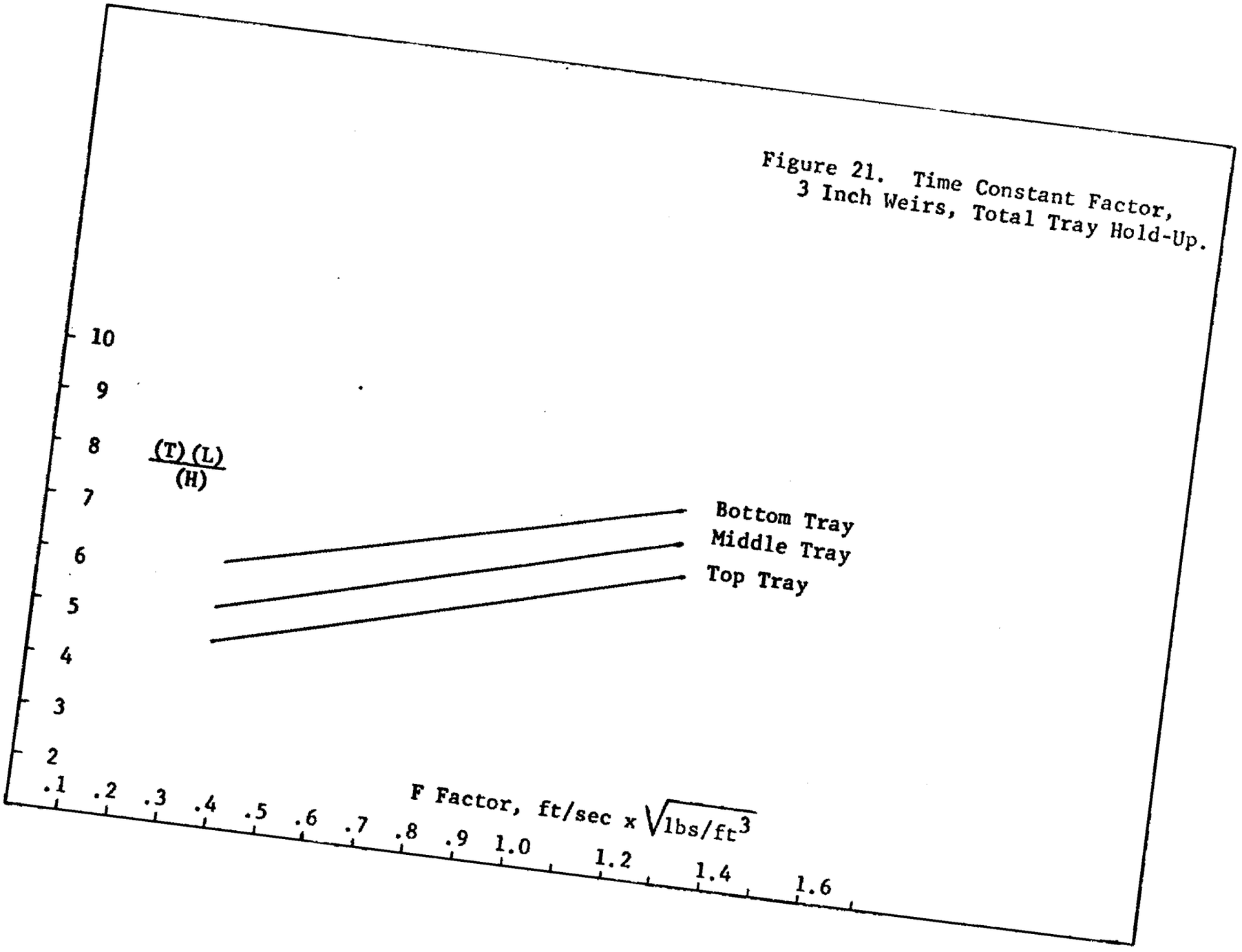
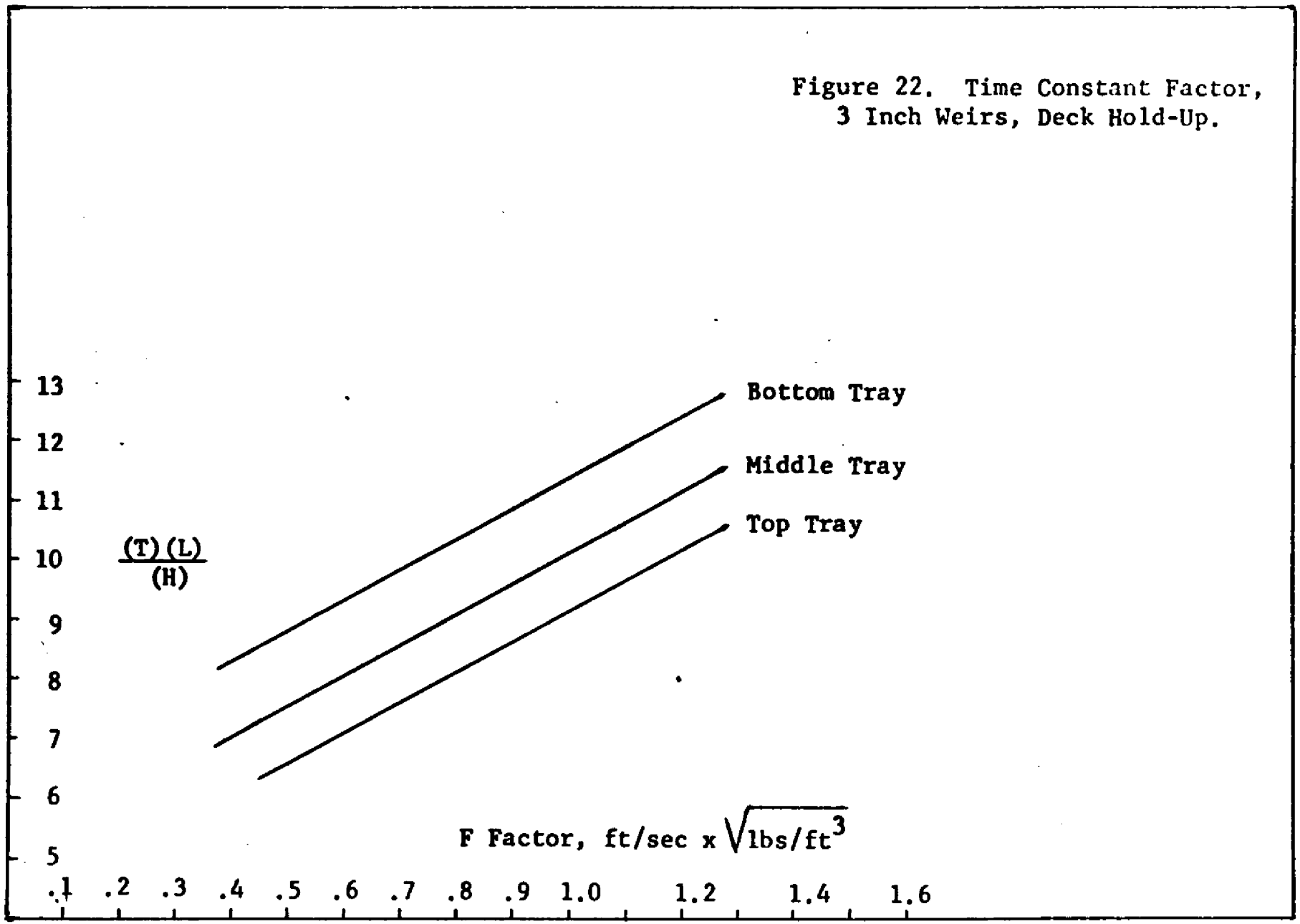


Figure 22. Time Constant Factor,
3 Inch Weirs, Deck Hold-Up.



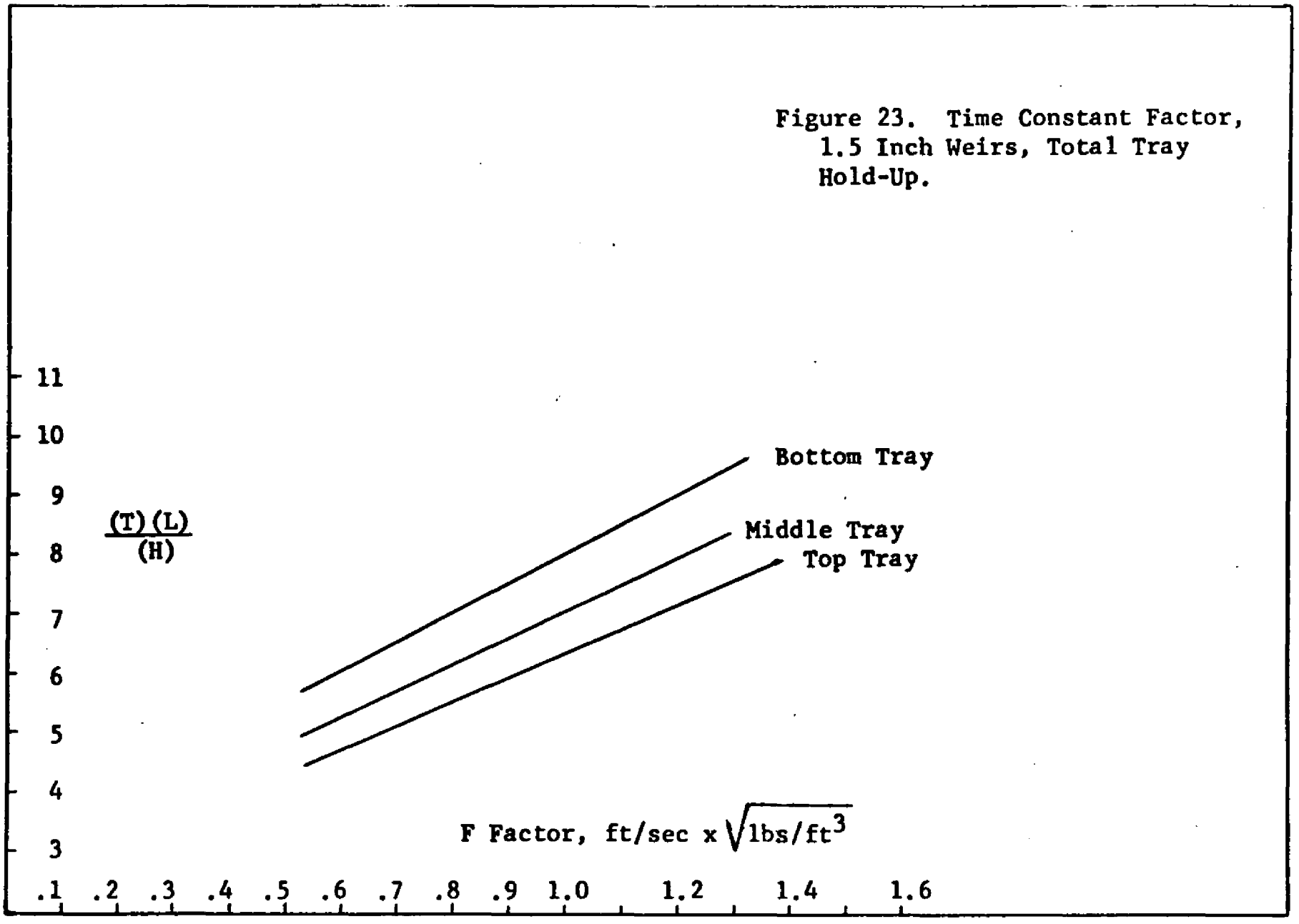


Figure 23. Time Constant Factor, 1.5 Inch Weirs, Total Tray Hold-Up.

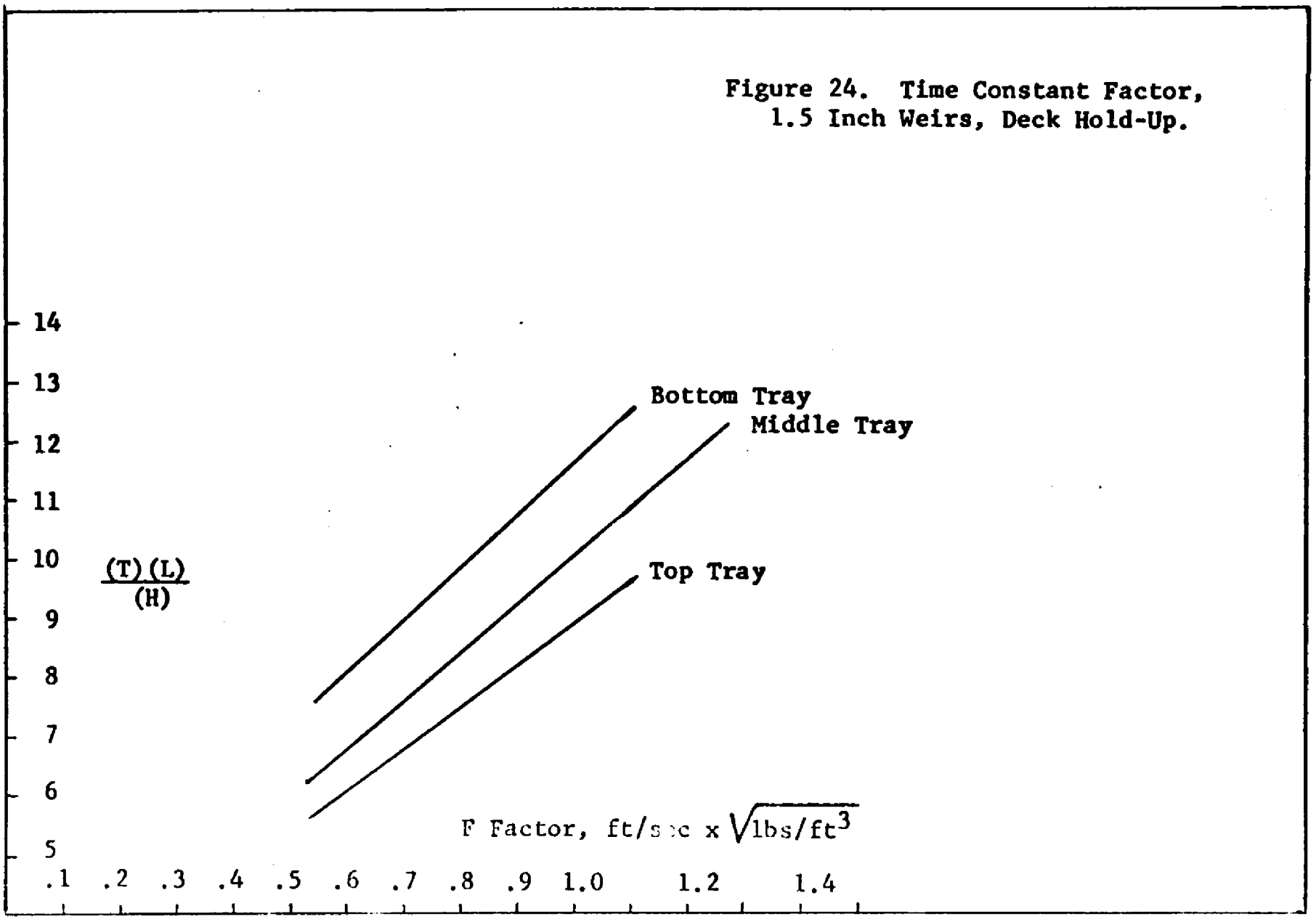
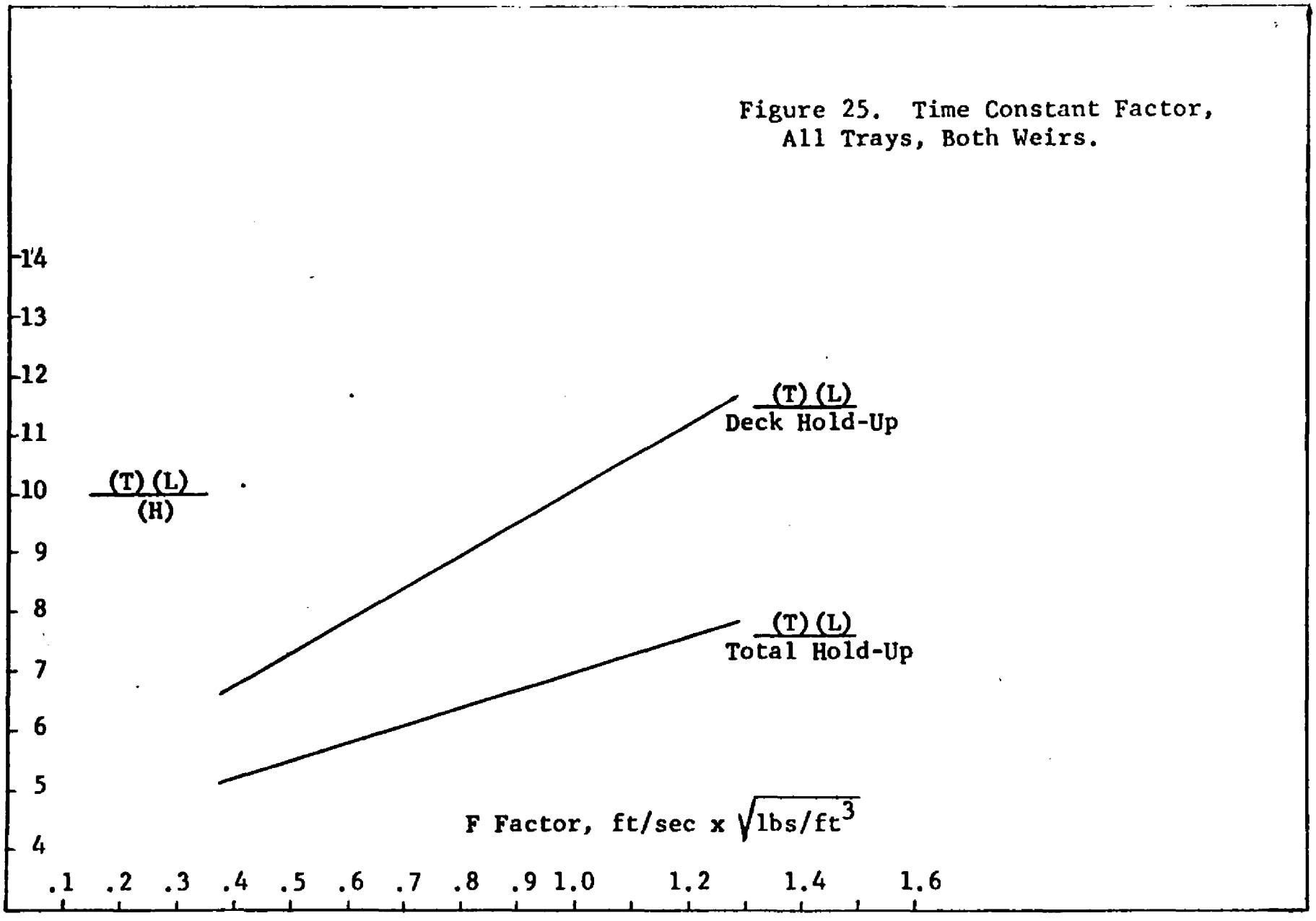


Figure 24. Time Constant Factor, 1.5 Inch Weirs, Deck Hold-Up.

Figure 25. Time Constant Factor,
All Trays, Both Weirs.



between the predicted and observed mol per cent is given along with this difference as a per cent of the total change encountered in the tray composition. Also for each run the average error is given both in its mol per cent value and as a per cent of the total change encountered. Table VII gives a summary of all runs made, the error experienced in each, and the average error experienced. The average per cent error of 2.53 on an absolute basis appears quite good.

As a check on the value of other correlations of the time constant, comparisons similar in nature to Table VII were made. One such comparison was made based on a single relationship for all trays and weir heights considered collectively (Figure 25 was used) and comparing the results both on a deck hold-up basis and on a total tray hold-up basis. The results of this comparison are given in Table VIII for the total hold-up basis and in Table IX for the deck hold-up basis.

From a comparison of these three tables it can be seen that the best prediction is achieved, as would be expected, by the time constants for the individual trays and weir heights. The results achieved by the single time constant relationship are surprisingly good, however, and it might be noted that the total hold-up basis yields slightly better results.

TABLE VII

RESULTS OF PREDICTION OF TRANSIENT COMPOSITION USING TIME CONSTANTS FOR INDIVIDUAL TRAYS AND BASED ON TOTAL HOLD-UP

RUN NUMBER	TRAY NUMBER	NUMBER OF OBSERVATIONS	AVERAGE ERROR FOR THE TRAY	ERROR AS PCT OF CHANGE IN X
101	1	3	-.57	-6.47
101	3	6	1.29	4.07
101	5	10	1.72	6.26
102	1	7	.00	.11
102	3	12	.36	2.14
102	5	8	.14	.96
103	1	15	-1.11	-3.57
103	3	16	2.59	7.13
103	5	8	1.06	9.47
104	1	9	-.01	-.99
104	3	13	-.02	-.40
104	5	15	.07	1.01
105	1	13	-.17	-2.39
105	3	14	-.35	-1.51
105	5	15	.29	2.55
106	1	8	.12	3.13
106	3	7	.55	3.23
106	5	13	-.62	-3.23
107	1	8	-.27	-2.13
107	3	15	-1.05	-3.95
107	5	11	-.08	-.84
108	1	7	.15	2.51
108	3	8	.42	2.12
108	5	14	-.12	-.64
109	1	18	-1.99	-6.45
109	3	18	-.16	-.40
109	5	17	.78	4.68
110	1	7	-.02	-1.48
110	3	7	.07	1.16
110	5	8	.02	.32
111	1	9	.15	2.81
111	3	6	-1.02	-5.80
111	5	8	-.33	-1.77
112	1	7	.18	2.69
112	3	8	.55	2.69
112	5	9	.17	1.41
113	1	9	.05	1.19
113	3	8	.29	3.29
113	5	7	.10	2.77
114	1	7	.45	3.39
114	3	10	-1.06	-3.97
114	5	12	.32	2.47

115	1	9	.24	3.18
115	3	9	.19	1.01
115	5	9	.51	2.71
116	1	9	.03	.78
116	3	9	-.16	-1.66
116	5	6	.01	.17
117	1	9	.18	2.00
117	3	9	.33	1.45
117	5	12	.21	1.14
118	1	3	-.20	-4.50
118	3	3	.26	1.22
119	1	8	-.25	-1.72
119	3	7	-.05	-.16
119	5	10	-.07	-.47

AVERAGE ERROR, MOL PERCENT 0.07

AVERAGE ERROR ON AN ABSOLUTE BASIS, MOL PERCENT 0.42

AVERAGE PERCENT ERROR 0.58

AVERAGE PERCENT ERROR ON AN ABSOLUTE BASIS 2.53

TOTAL OBSERVATIONS 542

TABLE VIII

RESULTS OF PREDICTION OF TRANSIENT COMPOSITION USING ONE SINGLE TIME CONSTANT RELATIONSHIP BASED ON TOTAL HOLD-UP

RUN NUMBER	TRAY NUMBER	NUMBER OF OBSERVATIONS	AVERAGE ERROR FOR THE TRAY	ERROR AS PCT OF CHANGE IN X
101	1	3	-.79	-8.92
101	3	6	1.43	4.53
101	5	10	2.79	10.15
102	1	7	-.11	-3.10
102	3	12	.39	2.31
102	5	8	.68	4.79
103	1	15	-.12	-.39
103	3	16	2.58	7.11
103	5	8	.77	6.82
104	1	9	-.04	-3.24
104	3	13	.02	.34
104	5	15	.33	4.94
105	1	13	.05	.72
105	3	14	-.40	-1.73
105	5	15	-.14	-1.23
106	1	8	.23	6.06
106	3	7	.57	3.35
106	5	13	-1.20	-6.25
107	1	8	.09	.71
107	3	15	-.94	-3.52
107	5	11	-.31	-3.22
108	1	7	.31	5.22
108	3	8	.57	2.88
108	5	14	-.43	-2.30
109	1	18	-1.18	-3.83
109	3	18	.10	.26
109	5	17	.54	3.25
110	1	7	-.08	-4.64
110	3	7	-.00	-.00
110	5	8	.10	1.36
111	1	9	.34	6.11
111	3	6	-.83	-4.69
111	5	8	-.53	-2.85
112	1	7	-.23	-3.31
112	3	8	-.07	-.33
112	5	9	.25	2.08
113	1	9	-.17	-4.39
113	3	8	.04	.49
113	5	7	.13	3.42
114	1	7	1.10	8.24
114	3	10	-.44	-1.66
114	5	12	.17	1.33

115	1	9	.10	1.38
115	3	9	.30	1.56
115	5	9	1.15	6.07
116	1	9	-.04	-1.25
116	3	9	-.09	-.97
116	5	6	.34	4.34
117	1	9	.33	3.71
117	3	9	.11	.51
117	5	12	-.48	-2.52
118	1	3	-.23	-5.26
118	3	3	.49	2.32
119	1	8	-.15	-1.06
119	3	7	-.57	-2.06
119	5	10	-.79	-5.32

AVERAGE ERROR, MOL PERCENT 0.11

AVERAGE ERROR ON AN ABSOLUTE BASIS, MOL PERCENT 0.48

AVERAGE PERCENT ERROR 0.51

AVERAGE PERCENT ERROR ON AN ABSOLUTE BASIS 3.29

TOTAL OBSERVATIONS 542

TABLE IX

RESULTS OF PREDICTION OF TRANSIENT COMPOSITION USING ONE SINGLE TIME CONSTANT RELATIONSHIP BASED ON DECK HOLD-UP

RUN NUMBER	TRAY NUMBER	NUMBER OF OBSERVATIONS	AVERAGE ERROR FOR THE TRAY	ERROR AS PCT OF CHANGE IN X
101	1	3	-.73	-8.29
101	3	6	1.75	5.53
101	5	10	3.02	10.99
102	1	7	-.09	-2.44
102	3	12	.50	2.98
102	5	8	.78	5.45
103	1	15	-.29	-.95
103	3	16	2.38	6.56
103	5	8	.72	6.39
104	1	9	-.03	-2.45
104	3	13	.06	1.16
104	5	15	.38	5.66
105	1	13	-.01	-.21
105	3	14	-.62	-2.71
105	5	15	-.25	-2.18
106	1	8	.22	5.74
106	3	7	.53	3.08
106	5	13	-1.26	-6.58
107	1	8	.08	.60
107	3	15	-.96	-3.61
107	5	11	-.32	-3.32
108	1	7	.29	4.91
108	3	8	.50	2.51
108	5	14	-.49	-2.60
109	1	18	-1.20	-3.89
109	3	18	.08	.21
109	5	17	.54	3.21
110	1	7	-.06	-3.66
110	3	7	.08	1.30
110	5	8	.19	2.40
111	1	9	.30	5.39
111	3	6	-.95	-5.38
111	5	8	-.68	-3.64
112	1	7	-.31	-4.59
112	3	8	-.32	-1.55
112	5	9	.09	.76
113	1	9	-.22	-5.61
113	3	8	-.06	-.68
113	5	7	.08	2.19
114	1	7	1.27	9.50
114	3	10	-.07	-.27
114	5	12	.34	2.66

115	1	9	.04	.53
115	3	9	.13	.69
115	5	9	.99	5.25
116	1	9	-.07	-2.15
116	3	9	-.18	-1.86
116	5	6	.26	3.38
117	1	9	.40	4.41
117	3	9	.29	1.27
117	5	12	-.35	-1.87
118	1	3	-.24	-5.40
118	3	3	.46	2.21
119	1	8	-.17	-1.22
119	3	7	-.62	-2.22
119	5	10	-.81	-5.47

AVERAGE ERROR, MOL PERCENT 0.10

AVERAGE ERROR ON AN ABSOLUTE BASIS, MOL PERCENT 0.50

AVERAGE PERCENT ERROR 0.40

AVERAGE PERCENT ERROR ON AN ABSOLUTE BASIS 3.42

TOTAL OBSERVATIONS 542

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the experimental results presented in the preceding pages, several conclusions and recommendations may be offered.

(a) One of the basic aims of the project is certainly met in that the experimental column as designed and built is quite adequate for the determination of dynamic distillation data.

(b) The response of a distillation column tray to liquid flow rate perturbations is not dependent on the tray's position in a column when a small number of trays are considered, i.e., the liquid perturbation is felt immediately throughout the column.

(c) A simple linear lag is sufficient for correlating the response characteristics of a distillation column to liquid flow rate perturbations in the case where a small number of trays (5 in this case) are present in the column. This is, of course, a partial result of (b) above.

(d) The time constant associated with the simple linear lag is not dependent on either the magnitude or the direction of the liquid flow rate perturbation.

(e) The ratio of the tray time constant to the natural time constant for a simple well mixed tank, TL/H, appears to be a satisfactory means of correlating the tray time constant.

(f) The ratio of the time constant to the natural time constant of a well mixed tank seems to correlate rather well with the vapor loading F factor of the column.

(g) The ratio of the time constant to the natural time constant of a well mixed tank correlates satisfactorily whether the hold-up used is the simple tray deck hold-up or the total tray hold-up (downcomer included), although the inclusion of the downcomer hold-up appears to give slightly better results.

(h) Future studies in this area might well be directed toward:

1. The effect of system physical properties on the time constant.
2. The modifications which must be included in the simple linear lag concept for the case in which the distillation column includes a very large number of trays.

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APPENDIX A

NOMENCLATURE AND SYMBOLS

The nomenclature and symbols presented in this Appendix are used throughout this work except in the FORTRAN programs presented elsewhere in the dissertation. The special nomenclature used in these programs are presented with the program involved.

L = internal liquid rate, lb mols/min

V = internal vapor rate, lb mols/min

H = hold-up of the liquid phase, lb mols

h = hold-up of the vapor phase, lb mols

x = mol fraction of the more volatile component in the liquid phase

y = mol fraction of the more volatile component in the vapor phase

f = function of that which follows

$D = \frac{d}{dt}$, the differential operator

s = complex variable in Laplace transformation

X(s) = Laplace transform of x(t)

θ = ratio of elapsed time to time required for liquid to traverse a tray

m = slope of the vapor-liquid equilibrium curve

t = time, minutes

T = system time constant

e = natural logarithm base

Subscripts

n = value of the variable on stage n

n + 1 = value of the variable on the stage below n

n - 1 = value of the variable on the stage above n

o = initial value

∞ = final value

d = desired value

Superscripts

^{o} = steady state value

^{p} = Perturbation imposed

APPENDIX B

A FORGO PROGRAM FOR EXPERIMENTAL DATA COMPARISON TO PREDICTED TRANSIENT BEHAVIOR

1. LIST OF PROGRAM STATEMENTS

```
C  C
      DIMENSION ERROR(30)
  100 READ101,NRUN,N,NTRAY,CONST,XI,XF
  101 FORMAT(3I5,3F5.2)
      READ102,RALIQ,RAVAP,ACTOR,SUPVE,HUDEK,HUTRY
  102 FORMAT(6F10.4)
      RALQI=RAVAP
      PCTCH=((RALIQ-RALQI)/RALQI)*100.
      DCHU=HUTRY-HUDEK
      TAU=CONST*HUTRY/RALIQ
      DELX=XF-XI
      PUNCH501,NRUN
  501 FORMAT(22X10HRUN NUMBER,I5)
      PUNCH502,NTRAY
  502 FORMAT(22X11HTRAY NUMBER,I4//)
      PUNCH503
  503 FORMAT(1X10HOAPOR RAT+11X11HLIQUID RAT+13X14HCHA-G+ IM
     $POSED)
  504 FORMAT(1X10HLBMOLS/MIN11X10HLBMOLS/MIN14X14HIN LIQUID
     $RATE)
      PUNCH505,RAVAP,RALIQ,PCTCH
  505 FORMAT(F8.4,F22.4,F24.2,4H PCT//)
      PUNCH506
  506 FORMAT(1X37HTRAY DECK HOLD-UP   DOWNCOMER HOLD-UP10X10
     $HTOTAL TRAY)
      PUNCH507
  507 FORMAT(5X7HLB-MOLS13X7HLB-MOLS13X15HHOLD-UP LB-MOLS)
      PUNCH508,HUDEK,DCHU,HUTRY
  508 FORMAT(F11.4,F20.4,F23.4//)
      PUNCH509
  509 FORMAT(1X26HTRAY   RESPONSE   CONSTANT20X13HTIME CONST
     $ANT)
      PUNCH510
  510 FORMAT(1X27HPREDICTED FOR TOTAL HOLD-UP18X14HPREDICTED
     $, MIN)
      PUNCH511,CONST,TAU
  511 FORMAT(F12.3,F44.3//)
      PUNCH512
  512 FORMAT(1X12HINITIAL TRAY9X10HFINAL TRAY12X16HCHANGE   I
     $N  TRAY)
      PUNCH513
  513 FORMAT(3X7HMOL PCT13X7HMOL PCT18X7HMOL PCT)
      PUNCH514,XI,XF,DELX
  514 FORMAT(F9.2,F20.2,F25.2//)
      PUNCH515
```

```
515   FORMAT(1X24HSUPERFICIAL GAS VELOCITY14X21HVAPOR     F
     $   FACTOR)
      PUNCH516
516   FORMAT(1X24HIN BUBBLING AREA, FT/SEC14X22HFT/SEC X SQR
     $T(LBS/FT3))
      PUNCH517,SUPVE,ACTOR
517   FORMAT(F14.2,F38.3//)
      PUNCH518
518   FORMAT(20X25HEXPERIMENTAL OBSERVATIONS//)
      PUNCH519
519   FORMAT(17H OBSERVED    TIME 2(2X9HPREDICTED)19H VALUE
     $ ERROR OVER)
      PUNCH520
520   FORMAT(8H MOL PCT4X3HMIN5X7HMOL PCT6X25H-  OBSERVED
     $CHANGE IN X)
      TOTER=0
      I=1
      DO200I=1,N,1
      READ103,X,T
103   FORMAT(2F10.3)
      XC=XI+DELX*(1.-EXPF(-T/TAU))
      ERROR(I)=XC-X
      TOTER=TOTER+ERROR(I)
      PCTER=(ERROR(I)/ABSF(DELX))*100.
200   PUNCH521,X,T,XC,ERROR(I),PCTER
521   FORMAT(F7.2,F9.2,F10.2,F14.2,F13.2,4H PCT)
      XN=N
      AVGER=TOTER/XN
      PCAVE=(AVGER/ABSF(DELX))*100.
      PUNCH524
524   FORMAT(//)
      PUNCH522,AVGER
522   FORMAT(1X31HAVERAGE OF PREDICTED - OBSERVED,F7.2//)
      PUNCH523,PCAVE
523   FORMAT(1X30HAVERAGE OVER TOTAL CHANGE IN X,F9.2,4H PCT
     $//)
      PUNCH525,N
525   FORMAT(1X22HNUMBER OF OBSERVATIONS,I5)
      PUNCH526
526   FORMAT(1H160(1H+))
      GOTO100
      END
```

2. DEFINITION OF VARIABLES USED IN PROGRAM STATEMENTS

ACTOR=F FACTOR, FT/SEC X SQRT(LBS/FT3)
CONST=PREDICTED RESPONSE CONSTANT, DIMENSIONLESS
DCHU=DOWNCOMER HOLD-UP, LBMOLS
DELX=CHANGE IN LIQUID COMPOSITION ON THE TRAY, MOL PCT
ERROR=XC-X
HUDEK=TRAY DECK HOLD-UP, LBMOLS
HUTRY =TOTAL TRAY HOLD-UP,LBMOLS
N=NUMBER OF EXPERIMENTAL OBSERVATIONS

NRUN=RUN NUMBER
NTRAY=TRAY NUMBER
PCAVE=AVERAGE ERROR AS A PERCENT OF TOTAL CHANGE IN X
PCTCH=PERCENT CHANGE IN LIQUID RATE
PCTER=ERROR / DELX•EXPRESSED AS A PERCENT
RALIQ=ACTUAL RATE OF LIQUID FLOW• LBMOLS/MIN
RALQI=INITIAL RATE OF LIQUID FLOW BEFORE THE CHANGE
IN REFLUX OCCURRED• LBMOLS/MIN
RAVAP=RATE OF VAPOR FLOW• LBMOLS/MIN
SUPVE=SUPERFICIAL GAS VELOCITY IN THE BUBBLING AREA
OF 16 X 8 INCHES• FT/SEC
T=TIME IN MINUTES AFTER CHANGE IN LIQUID RATE
TAU=TIME CONSTANT• MINUTES
TOTER=TOTAL OF ERROR
X=LIQUID COMPOSITION AT TIME T• MOL PERCENT
XC=CALCULATED LIQUID COMPOSITION• MOL PERCENT
XF=FINAL LIQUID CONCENTRATION ON THE TRAY• MOL PCT
XI=INITIAL LIQUID CONCENTRATION ON THE TRAY• MOL PCT

3• RESULTS ARE GIVEN ON THE FOLLOWING PAGES

NOTE PREDICTED RESULTS ARE BASED ON INDIVIDUAL TRAY AND
WEIR HEIGHT TIME CONSTANTS•

RUN NUMBER 101
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1166	.2132	82.85 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1144	.0375	.1519

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.550	3.242

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
64.00	72.84	8.84

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
.96		.373

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
64.00	0.00	64.00	0.00	0.00 PCT
67.58	1.25	66.83	-.75	-8.50 PCT
70.02	2.75	69.06	-.96	-10.91 PCT

AVERAGE OF PREDICTED - OBSERVED -.57

AVERAGE OVER TOTAL CHANGE IN X -6.47 PCT

NUMBER OF OBSERVATIONS 3

RUN NUMBER 101
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1166	.2132	82.85 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1114	.0375	.1489

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.220	3.646

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
39.76	71.38	31.62

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
.96		.373

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
39.76	0.00	39.76	0.00	0.00 PCT
45.75	1.25	48.94	3.19	10.08 PCT
53.66	2.33	54.69	1.03	3.26 PCT
60.10	3.75	60.08	-.02	-.08 PCT
62.32	5.17	63.72	1.40	4.44 PCT
63.94	6.50	66.06	2.12	6.72 PCT

AVERAGE OF PREDICTED - OBSERVED 1.29

AVERAGE OVER TOTAL CHANGE IN X 4.07 PCT

NUMBER OF OBSERVATIONS 6

RUN NUMBER 101
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1166	.2132	82.85 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1055	.0355	.1410

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.070	4.014

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
18.74	46.24	27.50

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
.96	.373

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
18.74	0.00	18.74	0.00	0.00 PCT
17.32	.75	23.43	6.11	22.20 PCT
26.42	1.75	28.46	2.04	7.41 PCT
33.07	3.50	34.74	1.67	6.07 PCT
38.23	4.83	37.98	-.25	-.90 PCT
39.04	6.17	40.33	1.29	4.68 PCT
40.54	7.45	41.94	1.40	5.09 PCT
42.47	8.67	43.07	.60	2.17 PCT
41.13	9.92	43.92	2.79	10.13 PCT
42.93	11.07	44.50	1.57	5.69 PCT

AVERAGE OF PREDICTED - OBSERVED 1.72

AVERAGE OVER TOTAL CHANGE IN X 6.26 PCT

NUMBER OF OBSERVATIONS 10

RUN NUMBER 102
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1408	.1797	27.63 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1114	.0386	.1500

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.740	3.957

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
69.91	73.58	3.67

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.16	.451

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
69.91	0.00	69.91	0.00	0.00 PCT
70.14	.65	70.47	.33	8.88 PCT
71.33	1.63	71.15	-.18	-4.93 PCT
71.64	2.52	71.64	-.00	-.03 PCT
72.17	3.45	72.05	-.12	-3.39 PCT
72.37	4.27	72.33	-.04	-1.02 PCT
72.49	4.97	72.53	.04	1.22 PCT

AVERAGE OF PREDICTED - OBSERVED .00

AVERAGE OVER TOTAL CHANGE IN X .11 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 102
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1408	.1797	27.63 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1079	.0374	.1453

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.400	4.366

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
48.31	65.05	16.74

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.16		.451

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME . MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
48.31	0.00	48.31	0.00	0.00 PCT
50.26	.73	50.89	.63	3.75 PCT
53.61	1.83	54.04	.43	2.58 PCT
55.70	2.78	56.19	.49	2.95 PCT
57.59	3.75	57.96	.37	2.20 PCT
59.02	4.69	59.33	.31	1.86 PCT
59.88	5.58	60.39	.51	3.02 PCT
61.16	6.60	61.36	.20	1.18 PCT
61.67	7.50	62.05	.38	2.24 PCT
62.11	8.29	62.54	.43	2.59 PCT
63.60	10.88	63.66	.06	.39 PCT
63.66	12.72	64.14	.48	2.87 PCT

AVERAGE OF PREDICTED - OBSERVED .36

AVERAGE OVER TOTAL CHANGE IN X 2.14 PCT

NUMBER OF OBSERVATIONS 12

RUN NUMBER 102
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1408	.1797	27.63 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1009	.0350	.1359

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.250	4.727

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
17.01	31.30	14.29

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.16		.451

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
17.01	0.00	17.01	0.00	0.00 PCT
17.70	.19	17.57	-.13	-.89 PCT
19.29	1.31	20.47	1.18	8.25 PCT
22.47	2.33	22.57	.10	.71 PCT
24.48	3.31	24.21	-.27	-1.92 PCT
26.62	4.22	25.45	-1.17	-8.20 PCT
25.20	5.16	26.50	1.30	9.12 PCT
27.27	6.09	27.36	.09	.63 PCT

AVERAGE OF PREDICTED - OBSERVED .14

AVERAGE OVER TOTAL CHANGE IN X .96 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 103
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1490	.1025	-31.21 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1061	.0379	.1440

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.880	6.856

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
68.47	37.50	-30.97

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.25	.504

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
68.47	0.00	68.47	0.00	0.00 PCT
67.32	.69	65.50	-1.82	-5.86 PCT
65.73	1.49	62.42	-3.31	-10.69 PCT
64.11	2.19	60.00	-4.11	-13.27 PCT
62.23	3.03	57.41	-4.82	-15.57 PCT
59.16	3.97	54.86	-4.30	-13.90 PCT
56.43	4.85	52.77	-3.66	-11.83 PCT
53.26	6.01	50.39	-2.87	-9.27 PCT
49.57	7.40	48.02	-1.55	-4.99 PCT
44.86	9.70	45.02	.16	.53 PCT
42.47	10.75	43.96	1.49	4.80 PCT
40.48	12.58	42.44	1.96	6.34 PCT
38.99	14.08	41.47	2.48	8.01 PCT
38.52	16.20	40.42	1.90	6.12 PCT
37.75	18.45	39.60	1.85	5.97 PCT

AVERAGE OF PREDICTED - OBSERVED -1.11

AVERAGE OVER TOTAL CHANGE IN X -3.57 PCT

NUMBER OF OBSERVATIONS 15

RUN NUMBER 103
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1490	.1025	-31.21 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0987	.0353	.1340

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.530	7.229

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
41.31	5.00	-36.31

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
1.25		.504

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
41.31	0.00	41.31	0.00	0.00 PCT
38.94	.69	38.00	-.94	-2.58 PCT
35.29	1.36	35.08	-.21	-.57 PCT
31.47	2.05	32.34	.87	2.41 PCT
28.43	2.68	30.06	1.63	4.50 PCT
25.18	3.31	27.97	2.79	7.69 PCT
23.74	4.12	25.54	1.80	4.95 PCT
18.82	5.24	22.59	3.77	10.38 PCT
14.36	6.79	19.19	4.83	13.32 PCT
10.98	8.36	16.42	5.44	14.99 PCT
8.48	9.90	14.23	5.75	15.84 PCT
7.79	11.80	12.10	4.31	11.87 PCT
6.56	13.20	10.85	4.29	11.81 PCT
5.76	16.25	8.84	3.08	8.47 PCT
5.58	18.35	7.87	2.29	6.30 PCT
5.42	20.42	7.15	1.73	4.78 PCT

AVERAGE OF PREDICTED - OBSERVED 2.59

AVERAGE OVER TOTAL CHANGE IN X 7.13 PCT

NUMBER OF OBSERVATIONS 16

RUN NUMBER 103
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1490	.1025	-31.21 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0943	.0337	.1280

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.370	7.955

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
12.24	1.00	-11.24

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.25	.504

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
12.24	0.00	12.24	0.00	0.00 PCT
12.15	.37	11.73	-.42	-3.74 PCT
10.20	1.02	10.89	.69	6.11 PCT
8.40	1.72	10.05	1.65	14.72 PCT
8.12	2.32	9.40	1.28	11.36 PCT
7.09	2.98	8.73	1.64	14.57 PCT
6.13	3.72	8.04	1.91	17.01 PCT
5.48	4.67	7.25	1.77	15.74 PCT

AVERAGE OF PREDICTED - OBSERVED 1.06

AVERAGE OVER TOTAL CHANGE IN X 9.47 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 104
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1411	.1587	12.47 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1111	.0395	.1506

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.880	4.631

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
71.33	72.69	1.36

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC	F FACTOR X SQRT(LBS/FT3)
1.15		.449

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
71.33	0.00	71.33	0.00	0.00 PCT
71.53	.12	71.36	-.17	-12.15 PCT
71.61	.99	71.59	-.02	-1.34 PCT
71.67	1.73	71.75	.08	6.17 PCT
72.02	2.77	71.94	-.08	-5.72 PCT
72.02	3.68	72.08	.06	4.09 PCT
72.20	4.68	72.19	-.00	-.37 PCT
72.37	5.94	72.31	-.06	-4.20 PCT
72.37	7.71	72.43	.06	4.61 PCT

AVERAGE OF PREDICTED - OBSERVED -.01

AVERAGE OVER TOTAL CHANGE IN X -.99 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 104
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1411	.1587	12.47 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1085	.0386	.1471

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.520	5.117

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
57.86	63.30	5.44

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.15	.449

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
57.86	0.00	57.86	0.00	0.00 PCT
58.36	.49	58.36	-.00	-.06 PCT
59.21	1.41	59.17	-.04	-.73 PCT
59.94	2.16	59.73	-.21	-3.80 PCT
60.33	3.24	60.41	.08	1.51 PCT
60.91	4.10	60.86	-.05	-.94 PCT
61.27	5.42	61.41	.14	2.65 PCT
61.90	6.62	61.81	-.09	-1.69 PCT
62.11	8.19	62.20	.09	1.70 PCT
62.59	9.51	62.45	-.14	-2.54 PCT
62.70	10.89	62.65	-.05	-.87 PCT
62.87	12.40	62.82	-.05	-.96 PCT
62.93	14.19	62.96	.03	.56 PCT

AVERAGE OF PREDICTED - OBSERVED -.02

AVERAGE OVER TOTAL CHANGE IN X -.40 PCT

NUMBER OF OBSERVATIONS 13

RUN NUMBER 104
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1411	.1587	12.47 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1021	.0363	.1384

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.360	5.546

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
27.30	34.04	6.74

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
1.15		.449

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
27.30	0.00	27.30	0.00	0.00 PCT
27.54	.13	27.46	-.08	-1.24 PCT
28.50	1.03	28.44	-.06	-.86 PCT
29.75	1.87	29.23	-.52	-7.73 PCT
28.54	2.81	29.98	1.44	21.35 PCT
30.10	3.64	30.54	.44	6.58 PCT
31.45	4.54	31.07	-.38	-5.68 PCT
31.54	5.94	31.73	.19	2.82 PCT
31.96	7.71	32.36	.40	5.95 PCT
33.45	8.76	32.65	-.80	-11.86 PCT
33.17	10.40	33.01	-.16	-2.43 PCT
33.59	11.49	33.19	-.40	-5.92 PCT
32.93	13.08	33.40	.47	7.01 PCT
33.71	15.19	33.60	-.11	-1.57 PCT
33.17	17.62	33.76	.59	8.74 PCT

AVERAGE OF PREDICTED - OBSERVED .07

AVERAGE OVER TOTAL CHANGE IN X 1.01 PCT

NUMBER OF OBSERVATIONS 15

RUN NUMBER 105
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1418	.1239	-12.62 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1090	.0400	.1490

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.790	5.760

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
70.23	63.19	-7.04

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.18	.468

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
70.23	0.00	70.23	0.00	0.00 PCT
70.20	.16	70.04	-.16	-2.31 PCT
69.07	.83	69.29	.22	3.06 PCT
69.19	1.60	68.52	-.67	-9.48 PCT
68.38	2.26	67.95	-.43	-6.17 PCT
67.52	3.05	67.34	-.18	-2.61 PCT
67.52	3.72	66.88	-.64	-9.08 PCT
67.21	4.34	66.50	-.71	-10.03 PCT
66.61	5.37	65.96	-.65	-9.21 PCT
66.10	6.50	65.47	-.63	-8.98 PCT
65.02	7.90	64.98	-.04	-.62 PCT
63.97	9.39	64.57	.60	8.51 PCT
63.10	11.09	64.22	1.12	15.86 PCT

AVERAGE OF PREDICTED - OBSERVED -.17

AVERAGE OVER TOTAL CHANGE IN X -2.39 PCT

NUMBER OF OBSERVATIONS 13

RUN NUMBER 105
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1418	.1239	-12.62 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1031	.0379	.1410

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.460	6.214

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
47.89	24.97	-22.92

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.18		.468

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
47.89	0.00	47.89	0.00	0.00 PCT
46.35	.55	45.95	-.40	-1.75 PCT
44.90	1.17	43.96	-.94	-4.12 PCT
42.12	1.93	41.77	-.35	-1.53 PCT
40.96	2.73	39.74	-1.22	-5.32 PCT
39.43	3.40	38.23	-1.20	-5.23 PCT
39.11	4.04	36.93	-2.18	-9.50 PCT
37.07	4.85	35.47	-1.60	-6.98 PCT
34.55	5.80	33.98	-.57	-2.48 PCT
31.94	7.46	31.87	-.07	-.31 PCT
30.52	8.70	30.62	.10	.44 PCT
28.88	10.13	29.46	.58	2.53 PCT
27.21	11.73	28.44	1.23	5.37 PCT
25.75	13.65	27.52	1.77	7.71 PCT

AVERAGE OF PREDICTED - OBSERVED -.35

AVERAGE OVER TOTAL CHANGE IN X -1.51 PCT

NUMBER OF OBSERVATIONS 14

RUN NUMBER 105
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1418	.1239	-12.62 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0967	.0356	.1323

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.290	6.716

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
16.00	4.76	-11.24

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.18	.468

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
16.00	0.00	16.00	0.00	0.00 PCT
15.43	.16	15.74	.31	2.72 PCT
14.65	.83	14.69	.04	.39 PCT
13.43	1.65	13.55	.12	1.08 PCT
12.41	2.36	12.67	.26	2.31 PCT
11.20	3.09	11.86	.66	5.83 PCT
10.82	3.72	11.22	.40	3.56 PCT
10.71	4.34	10.65	-.06	-.53 PCT
10.28	5.28	9.88	-.40	-3.55 PCT
9.19	6.50	9.03	-.16	-1.42 PCT
8.69	7.90	8.23	-.46	-4.12 PCT
8.29	9.39	7.54	-.75	-6.70 PCT
7.22	11.09	6.92	-.30	-2.70 PCT
2.08	12.82	6.43	4.35	38.67 PCT
5.73	14.65	6.03	.30	2.66 PCT

AVERAGE OF PREDICTED - OBSERVED .29

AVERAGE OVER TOTAL CHANGE IN X 2.55 PCT

NUMBER OF OBSERVATIONS 15

RUN NUMBER 106
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1874	.1519	-18.94 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1050	.0394	.1444

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.170	4.915

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
72.89	69.05	-3.84

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
1.54		.607

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
72.89	0.00	72.89	0.00	0.00 PCT
72.28	.69	72.39	.11	2.79 PCT
71.82	1.29	72.00	.18	4.78 PCT
71.53	1.97	71.62	.09	2.39 PCT
71.15	2.72	71.26	.11	2.81 PCT
70.85	3.58	70.90	.05	1.39 PCT
70.46	4.17	70.69	.23	6.09 PCT
70.23	5.09	70.41	.18	4.77 PCT

AVERAGE OF PREDICTED - OBSERVED .12

AVERAGE OVER TOTAL CHANGE IN X 3.13 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 106
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1874	.1519	-18.94 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.1008	.0378	.1386

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.800	5.292

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
58.83	41.68	-17.15

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.54		.607

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
58.83	0.00	58.83	0.00	0.00 PCT
57.42	.42	57.52	.10	.59 PCT
55.97	.96	55.98	.01	.09 PCT
53.55	1.62	54.31	.76	4.42 PCT
51.43	2.36	52.66	1.23	7.17 PCT
50.37	3.06	51.30	.93	5.42 PCT
49.10	3.86	49.95	.85	4.96 PCT

AVERAGE OF PREDICTED - OBSERVED .55

AVERAGE OVER TOTAL CHANGE IN X 3.23 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 106
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1874	.1519	-18.94 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0943	.0354	.1297

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.61C	5.644

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
26.22	7.09	-19.13

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.54	.607

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
26.22	0.00	26.22	0.00	0.00 PCT
26.20	.13	25.78	-.42	-2.17 PCT
23.76	.69	24.02	.26	1.35 PCT
21.47	1.29	22.31	.84	4.40 PCT
21.44	1.97	20.58	-.86	-4.48 PCT
17.78	2.72	18.90	1.12	5.88 PCT
18.41	3.58	17.23	-1.18	-6.14 PCT
18.04	4.17	16.23	-1.81	-9.47 PCT
16.68	5.09	14.85	-1.83	-9.55 PCT
14.98	6.57	13.06	-1.92	-10.02 PCT
12.63	8.95	11.01	-1.62	-8.48 PCT
10.47	10.51	10.06	-.41	-2.14 PCT
9.59	12.00	9.37	-.22	-1.14 PCT

AVERAGE OF PREDICTED - OBSERVED -.62

AVERAGE OVER TOTAL CHANGE IN X -3.23 PCT

NUMBER OF OBSERVATIONS 13

RUN NUMBER 107
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2304	.1955	-15.15 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0979	.0396	.1375

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.580	3.925

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
67.42	54.56	-12.86

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.93		.775

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
67.42	0.00	67.42	0.00	0.00 PCT
66.52	.10	67.10	.58	4.48 PCT
65.16	.70	65.32	.16	1.24 PCT
63.89	1.46	63.42	-.47	-3.62 PCT
62.66	2.12	62.05	-.61	-4.72 PCT
61.60	2.75	60.94	-.66	-5.12 PCT
60.59	3.49	59.84	-.75	-5.79 PCT
58.97	4.62	58.52	-.45	-3.48 PCT

AVERAGE OF PREDICTED - OBSERVED -.27

AVERAGE OVER TOTAL CHANGE IN X -2.13 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 107
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2304	.1955	-15.15 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0916	.0370	.1286

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.210	4.085

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
38.64	12.00	-26.64

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
1.93		.775

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
38.64	0.00	38.64	0.00	0.00 PCT
37.16	.37	36.33	-.83	-3.10 PCT
34.02	1.06	32.55	-1.47	-5.51 PCT
31.41	1.79	29.19	-2.22	-8.34 PCT
29.57	2.43	26.70	-2.87	-10.79 PCT
28.91	3.08	24.53	-4.38	-16.43 PCT
24.24	3.90	22.25	-1.99	-7.45 PCT
21.66	4.97	19.89	-1.77	-6.64 PCT
18.13	6.42	17.53	-.60	-2.24 PCT
18.82	7.92	15.83	-2.99	-11.21 PCT
13.86	9.97	14.32	.46	1.73 PCT
12.52	12.13	13.37	.85	3.18 PCT
11.65	14.22	12.82	1.17	4.39 PCT
11.52	16.47	12.47	.95	3.58 PCT
12.37	18.58	12.28	-.09	-.33 PCT

AVERAGE OF PREDICTED - OBSERVED -1.05

AVERAGE OVER TOTAL CHANGE IN X -3.95 PCT

NUMBER OF OBSERVATIONS 15

RUN NUMBER 107
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2304	.1955	-15.15 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0872	.0352	.1224

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.990	4.376

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
12.30	2.66	-9.64

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.93	.775

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
12.30	0.00	12.30	0.00	0.00 PCT
11.41	.10	12.08	.67	6.97 PCT
12.03	.70	10.88	-1.15	-11.98 PCT
9.12	1.46	9.57	.45	4.62 PCT
8.20	2.12	8.60	.40	4.14 PCT
8.41	2.75	7.80	-.61	-6.30 PCT
6.68	3.49	7.00	.32	3.35 PCT
6.54	4.62	6.01	-.53	-5.45 PCT
5.58	5.93	5.15	-.43	-4.50 PCT
4.36	7.51	4.39	.03	.34 PCT
3.79	9.56	3.74	-.05	-.47 PCT

AVERAGE OF PREDICTED - OBSERVED -.08

AVERAGE OVER TOTAL CHANGE IN X -.84 PCT

NUMBER OF OBSERVATIONS 11

RUN NUMBER 108
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2866	.2521	-12.04 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0937	.0426	.1363

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.020	3.255

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
70.28	64.40	-5.88

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.37	.944

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
70.28	0.00	70.28	0.00	0.00 PCT
70.05	.09	70.12	.07	1.18 PCT
68.76	.66	69.20	.44	7.50 PCT
68.24	1.28	68.37	.13	2.18 PCT
67.75	1.97	67.61	-.14	-2.38 PCT
66.61	2.67	66.99	.38	6.44 PCT
66.13	3.70	66.29	.16	2.66 PCT

AVERAGE OF PREDICTED - OBSERVED .15

AVERAGE OVER TOTAL CHANGE IN X 2.51 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 108
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2866	.2521	-12.04 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0890	.0404	.1294

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.640	3.408

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
51.91	32.00	-19.91

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
2.37		.944

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
51.91	0.00	51.91	0.00	0.00 PCT
50.07	.40	49.71	-.36	-1.83 PCT
46.71	.98	46.93	.22	1.13 PCT
44.15	1.61	44.41	.26	1.33 PCT
41.48	2.31	42.11	.63	3.16 PCT
40.68	3.11	39.99	-.69	-3.44 PCT
37.26	4.08	38.01	.75	3.79 PCT
33.86	5.13	36.42	2.56	12.86 PCT

AVERAGE OF PREDICTED - OBSERVED .42

AVERAGE OVER TOTAL CHANGE IN X 2.12 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 108
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2866	.2521	-12.04 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0838	.0380	.1218

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.390	3.570

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
23.48	4.63	-18.85

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
2.37		.944

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
23.48	0.00	23.48	0.00	0.00 PCT
18.72	.66	20.30	1.58	8.37 PCT
16.34	1.28	17.80	1.46	7.75 PCT
15.06	1.97	15.49	.43	2.26 PCT
13.48	2.67	13.55	.07	.39 PCT
12.03	3.70	11.32	-.71	-3.78 PCT
11.44	4.78	9.57	-1.87	-9.91 PCT
9.77	5.89	8.25	-1.52	-8.06 PCT
8.82	7.33	7.05	-1.77	-9.39 PCT
6.70	8.70	6.28	-.42	-2.24 PCT
6.03	10.01	5.77	-.26	-1.37 PCT
6.10	11.46	5.39	-.71	-3.76 PCT
4.36	12.58	5.19	.83	4.38 PCT
3.82	13.78	5.03	1.21	6.40 PCT

AVERAGE OF PREDICTED - OBSERVED -.12

AVERAGE OVER TOTAL CHANGE IN X -.64 PCT

NUMBER OF OBSERVATIONS 14

RUN NUMBER 109
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2991	.2223	-25.68 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0895	.0402	.1297

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.190	3.612

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
71.24	40.45	-30.79

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.50	1.010

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
71.24	0.00	71.24	0.00	0.00 PCT
71.18	.10	70.40	-.78	-2.54 PCT
68.13	.77	65.33	-2.80	-9.10 PCT
66.58	1.37	61.52	-5.06	-16.43 PCT
63.04	1.98	58.25	-4.79	-15.57 PCT
59.08	2.89	54.28	-4.80	-15.58 PCT
56.86	3.57	51.91	-4.95	-16.08 PCT
54.55	4.18	50.13	-4.42	-14.36 PCT
50.90	5.14	47.87	-3.03	-9.85 PCT
49.57	6.17	46.03	-3.54	-11.50 PCT
47.57	7.28	44.55	-3.02	-9.80 PCT
43.90	8.67	43.24	-.66	-2.14 PCT
42.78	9.98	42.39	-.39	-1.26 PCT
41.76	11.10	41.87	.11	.37 PCT
39.98	12.97	41.30	1.32	4.28 PCT
40.43	15.14	40.92	.49	1.58 PCT
40.63	17.14	40.72	.09	.28 PCT
40.18	18.18	40.65	.47	1.53 PCT

AVERAGE OF PREDICTED - OBSERVED -1.99

AVERAGE OVER TOTAL CHANGE IN X -6.45 PCT

NUMBER OF OBSERVATIONS 18

RUN NUMBER 109
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2991	.2223	-25.68 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0838	.0376	.1214

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.820	3.724

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
48.40	8.50	-39.90

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.50	1.010

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
48.40	0.00	48.40	0.00	0.00 PCT
46.92	.36	44.72	-2.20	-5.50 PCT
42.17	1.03	38.76	-3.41	-8.55 PCT
36.14	1.68	33.91	-2.23	-5.58 PCT
29.62	2.44	29.22	-.40	-.99 PCT
25.58	3.18	25.49	-.09	-.23 PCT
22.17	3.87	22.62	.45	1.12 PCT
19.87	4.51	20.39	.52	1.30 PCT
17.70	5.44	17.76	.06	.15 PCT
15.26	6.48	15.50	.24	.61 PCT
13.24	7.60	13.69	.45	1.12 PCT
11.44	8.98	12.08	.64	1.60 PCT
9.99	10.28	11.03	1.04	2.59 PCT
9.99	11.40	10.37	.38	.95 PCT
8.80	13.34	9.61	.81	2.03 PCT
8.99	15.46	9.13	.14	.35 PCT
8.10	17.43	8.87	.77	1.93 PCT
8.80	18.42	8.78	-.02	-.04 PCT

AVERAGE OF PREDICTED - OBSERVED -.16

AVERAGE OVER TOTAL CHANGE IN X -.40 PCT

NUMBER OF OBSERVATIONS 18

RUN NUMBER 109
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.2991	.2223	-25.68 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0802	.0359	.1161

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.530	3.933

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
18.11	1.40	-16.71

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.50	1.010

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
18.11	0.00	18.11	0.00	0.00 PCT
14.27	.77	15.14	.87	5.20 PCT
11.85	1.37	13.19	1.34	8.05 PCT
9.60	1.98	11.50	1.90	11.37 PCT
7.51	2.89	9.41	1.90	11.39 PCT
6.26	3.57	8.14	1.88	11.26 PCT
5.97	4.18	7.17	1.20	7.20 PCT
4.69	5.14	5.92	1.23	7.37 PCT
4.08	6.17	4.88	.80	4.79 PCT
3.27	7.28	4.02	.75	4.51 PCT
2.58	8.67	3.24	.66	3.97 PCT
2.32	9.98	2.72	.40	2.40 PCT
2.32	11.10	2.39	.07	.44 PCT
1.75	12.97	2.02	.27	1.60 PCT
1.69	15.14	1.76	.07	.39 PCT
1.64	17.14	1.61	-.03	-.16 PCT
1.60	18.18	1.56	-.04	-.21 PCT

AVERAGE OF PREDICTED - OBSERVED .78

AVERAGE OVER TOTAL CHANGE IN X 4.68 PCT

NUMBER OF OBSERVATIONS 17

RUN NUMBER 110
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3942	.4225	7.18 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0861	.0473	.1334

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.790	2.144

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
70.11	71.73	1.62

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.21	1.254

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
70.11	0.00	70.11	0.00	0.00 PCT
70.37	.09	70.18	-.19	-11.94 PCT
70.49	.66	70.54	.05	3.04 PCT
70.77	1.24	70.82	.05	3.18 PCT
71.15	1.92	71.07	-.08	-5.03 PCT
71.27	2.63	71.25	-.02	-.93 PCT
71.35	3.23	71.37	.02	1.29 PCT

AVERAGE OF PREDICTED - OBSERVED -.02

AVERAGE OVER TOTAL CHANGE IN X -1.48 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 110
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3942	.4225	7.18 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0839	.0471	.1310

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.430	2.304

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
54.07	60.50	6.43

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.21	1.254

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
54.07	0.00	54.07	0.00	0.00 PCT
54.88	.40	55.09	.21	3.34 PCT
56.38	.96	56.26	-.12	-1.85 PCT
56.57	1.53	57.19	.62	9.65 PCT
58.27	2.28	58.11	-.16	-2.49 PCT
58.55	2.91	58.68	.13	2.05 PCT
59.30	3.57	59.13	-.17	-2.57 PCT

AVERAGE OF PREDICTED - OBSERVED .07

AVERAGE OVER TOTAL CHANGE IN X 1.16 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 110
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3942	.4225	7.18 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0789	.0434	.1223

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.110	2.348

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
23.28	30.99	7.71

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.21	1.254

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
23.28	0.00	23.28	0.00	0.00 PCT
23.72	.09	23.57	-.15	-1.95 PCT
24.74	.66	25.17	.43	5.57 PCT
26.82	1.24	26.44	-.38	-4.88 PCT
27.36	1.92	27.59	.23	2.94 PCT
28.56	2.63	28.48	-.08	-1.10 PCT
28.91	3.23	29.04	.13	1.72 PCT
29.50	3.89	29.52	.02	.25 PCT

AVERAGE OF PREDICTED - OBSERVED .02

AVERAGE OVER TOTAL CHANGE IN X .32 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 111
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3958	.3388	-14.40 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0833	.0444	.1277

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.870	2.589

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
72.34	66.85	-5.49

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.24	1.281

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
72.34	0.00	72.34	0.00	0.00 PCT
71.38	.09	72.15	.77	14.07 PCT
71.06	.62	71.17	.11	2.02 PCT
70.02	1.27	70.21	.19	3.49 PCT
69.27	1.83	69.56	.29	5.25 PCT
69.13	2.49	68.95	-.18	-3.30 PCT
68.73	3.12	68.50	-.23	-4.27 PCT
67.93	3.82	68.11	.18	3.20 PCT
67.44	4.82	67.70	.26	4.80 PCT

AVERAGE OF PREDICTED - OBSERVED .15

AVERAGE OVER TOTAL CHANGE IN X 2.81 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 111
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3958	.3388	-14.40 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0802	.0428	.1230

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.690	2.719

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
60.33	42.75	-17.58

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.24	1.281

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
60.33	0.00	60.33	0.00	0.00 PCT
59.05	.36	58.15	-.90	-5.12 PCT
56.19	.98	55.01	-1.18	-6.71 PCT
53.36	1.57	52.62	-.74	-4.22 PCT
52.42	2.14	50.75	-1.67	-9.48 PCT
50.68	2.79	49.05	-1.63	-9.27 PCT

AVERAGE OF PREDICTED - OBSERVED -1.02

AVERAGE OVER TOTAL CHANGE IN X -5.80 PCT

NUMBER OF OBSERVATIONS 6

RUN NUMBER 111
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3958	.3388	-14.40 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0755	.0402	.1157

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.170	2.790

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
32.79	14.14	-18.65

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.24	1.281

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
32.79	0.00	32.79	0.00	0.00 PCT
30.31	.62	29.07	-1.24	-6.63 PCT
25.62	1.27	25.97	.35	1.88 PCT
24.41	1.83	23.82	-.59	-3.17 PCT
21.85	2.49	21.78	-.07	-.38 PCT
20.66	3.12	20.24	-.42	-2.27 PCT
18.96	3.82	18.88	-.08	-.41 PCT
18.04	4.82	17.45	-.59	-3.14 PCT

AVERAGE OF PREDICTED - OBSERVED -.33

AVERAGE OVER TOTAL CHANGE IN X -1.77 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 112
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1658	.2015	21.53 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0914	.0251	.1165

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.500	2.602

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
61.53	68.36	6.83

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.37	.542

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
61.53	0.00	61.53	0.00	0.00 PCT
62.87	.67	63.08	.21	3.08 PCT
63.58	1.23	64.10	.52	7.66 PCT
65.02	1.86	65.02	-.00	-.02 PCT
65.84	2.54	65.79	-.05	-.78 PCT
66.04	3.20	66.36	.32	4.74 PCT
66.78	4.32	67.06	.28	4.13 PCT

AVERAGE OF PREDICTED - OBSERVED .18

AVERAGE OVER TOTAL CHANGE IN X 2.69 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 112
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1658	.2015	21.53 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0877	.0242	.1119

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.010	2.782

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
32.50	52.81	20.31

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.37	.542

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
32.50	0.00	32.50	0.00	0.00 PCT
34.36	.34	34.84	.48	2.35 PCT
37.61	.91	38.17	.56	2.74 PCT
40.86	1.56	41.22	.36	1.76 PCT
42.12	2.19	43.57	1.45	7.12 PCT
45.23	2.82	45.44	.21	1.03 PCT
46.79	3.54	47.12	.33	1.62 PCT
47.89	4.58	48.89	1.00	4.95 PCT

AVERAGE OF PREDICTED - OBSERVED .55

AVERAGE OVER TOTAL CHANGE IN X 2.69 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 112
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1658	.2015	21.53 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0822	.0226	.1048

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.780	3.006

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
8.64	20.50	11.86

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.37	.542

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
8.64	0.00	8.64	0.00	0.00 PCT
9.29	.67	11.01	1.72	14.50 PCT
11.00	1.23	12.62	1.62	13.68 PCT
13.77	1.86	14.11	.34	2.88 PCT
14.71	2.54	15.41	.70	5.86 PCT
15.85	3.20	16.41	.56	4.72 PCT
18.86	4.32	17.68	-1.18	-9.93 PCT
18.82	4.88	18.16	-.66	-5.56 PCT
20.75	6.55	19.16	-1.59	-13.43 PCT

AVERAGE OF PREDICTED - OBSERVED .17

AVERAGE OVER TOTAL CHANGE IN X 1.41 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 113
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1641	.1817	10.73 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0903	.0250	.1153

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.520	2.868

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
59.83	63.80	3.97

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.37	.547

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
59.83	0.00	59.83	0.00	0.00 PCT
59.85	.56	60.53	.68	17.23 PCT
60.77	1.16	61.15	.38	9.59 PCT
61.41	1.80	61.68	.27	6.81 PCT
62.03	2.36	62.06	.03	.66 PCT
62.73	3.36	62.57	-.16	-4.04 PCT
63.38	4.90	63.08	-.30	-7.54 PCT
63.52	6.38	63.37	-.15	-3.76 PCT
63.89	8.06	63.56	-.33	-8.29 PCT

AVERAGE OF PREDICTED - OBSERVED .05

AVERAGE OVER TOTAL CHANGE IN X 1.19 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 113
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1641	.1817	10.73 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0853	.0236	.1089

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.040	3.021

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
30.31	38.98	8.67

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.37	.547

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
30.31	0.00	30.31	0.00	0.00 PCT
32.34	.29	31.10	-1.24	-14.26 PCT
32.08	.82	32.37	.29	3.36 PCT
31.56	1.44	33.60	2.04	23.50 PCT
35.92	2.07	34.61	-1.31	-15.10 PCT
34.62	2.69	35.42	.80	9.24 PCT
34.84	3.77	36.49	1.65	19.04 PCT
37.38	5.19	37.42	.04	.51 PCT

AVERAGE OF PREDICTED - OBSERVED .29

AVERAGE OVER TOTAL CHANGE IN X 3.29 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 113
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1641	.1817	10.73 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0806	.0223	.1029

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.800	3.285

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
6.92	10.59	3.67

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X SQRT(LBS/FT3)	F FACTOR
1.37		.547

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
6.92	0.00	6.92	0.00	0.00 PCT
6.75	.56	7.50	.75	20.31 PCT
8.00	1.16	8.01	.01	.33 PCT
8.76	1.80	8.47	-.29	-7.95 PCT
8.55	2.36	8.80	.25	6.84 PCT
9.52	4.90	9.76	.24	6.66 PCT

AVERAGE OF PREDICTED - OBSERVED .10

AVERAGE OVER TOTAL CHANGE IN X 2.77 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 114
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1802	.1442	-19.98 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0867	.0248	.1115

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
4.790	3.704

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
66.21	52.88	-13.33

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.51	.609

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
66.21	0.00	66.21	0.00	0.00 PCT
64.11	.68	63.97	-.14	-1.02 PCT
62.56	1.26	62.37	-.19	-1.45 PCT
60.60	1.90	60.86	.26	1.96 PCT
58.97	2.52	59.63	.66	4.96 PCT
57.64	3.16	58.56	.92	6.90 PCT
55.45	4.26	57.10	1.65	12.38 PCT

AVERAGE OF PREDICTED - OBSERVED .45

AVERAGE OVER TOTAL CHANGE IN X 3.39 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 114
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1802	.1442	-19.98 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0815	.0232	.1047

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
5.330	3.870

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
40.56	13.79	-26.77

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
1.51	.609

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
40.56	0.00	40.56	0.00	0.00 PCT
39.66	.36	38.18	-1.48	-5.52 PCT
37.43	.96	34.68	-2.75	-10.28 PCT
33.50	1.59	31.54	-1.96	-7.32 PCT
31.14	2.19	28.99	-2.15	-8.03 PCT
28.75	2.84	26.64	-2.11	-7.88 PCT
26.11	3.45	24.77	-1.34	-5.02 PCT
21.80	4.57	22.01	.21	.78 PCT
18.82	6.02	19.44	.62	2.32 PCT
17.12	7.71	17.44	.32	1.20 PCT

AVERAGE OF PREDICTED - OBSERVED -1.06

AVERAGE OVER TOTAL CHANGE IN X -3.97 PCT

NUMBER OF OBSERVATIONS 10

RUN NUMBER 114
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.1802	.1442	-19.98 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0777	.0221	.0998

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.120	4.236

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
13.86	1.00	-12.86

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR FT/SEC X	F FACTOR SQRT(LBS/FT3)
1.51		.609

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
13.86	0.00	13.86	0.00	0.00 PCT
11.87	.68	11.95	.08	.64 PCT
9.52	1.26	10.55	1.03	8.02 PCT
8.26	1.90	9.21	.95	7.40 PCT
7.14	2.52	8.09	.95	7.41 PCT
6.61	3.16	7.10	.49	3.80 PCT
5.25	4.26	5.70	.45	3.53 PCT
3.95	5.72	4.33	.38	2.97 PCT
3.17	7.43	3.23	.06	.43 PCT
2.60	9.24	2.45	-.15	-1.15 PCT
2.18	11.55	1.84	-.34	-2.63 PCT
1.60	13.80	1.49	-.11	-.82 PCT

AVERAGE OF PREDICTED - OBSERVED .32

AVERAGE OVER TOTAL CHANGE IN X 2.47 PCT

NUMBER OF OBSERVATIONS 12

RUN NUMBER 115
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3244	.3898	20.16 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0766	.0304	.1070

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.970	1.803

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
60.46	68.00	7.54

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.66	1.042

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
60.46	0.00	60.46	0.00	0.00 PCT
60.66	.10	60.87	.21	2.74 PCT
64.20	.81	63.19	-1.01	-13.42 PCT
65.13	1.59	64.88	-.25	-3.35 PCT
65.93	2.16	65.72	-.21	-2.74 PCT
66.33	2.95	66.53	.20	2.67 PCT
64.93	3.77	67.07	2.14	28.35 PCT
67.01	5.11	67.56	.55	7.25 PCT
67.21	6.10	67.74	.53	7.08 PCT

AVERAGE OF PREDICTED - OBSERVED .24

AVERAGE OVER TOTAL CHANGE IN X 3.18 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 115
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3244	.3898	20.16 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0748	.0297	.1045

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.310	1.960

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
39.68	58.74	19.06

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.66	1.042

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
39.68	0.00	39.68	0.00	0.00 PCT
40.58	.45	43.59	3.01	15.79 PCT
49.33	1.18	48.30	-1.03	-5.39 PCT
52.02	1.85	51.32	-.70	-3.65 PCT
53.63	2.57	53.60	-.03	-.13 PCT
55.31	3.38	55.34	.03	.17 PCT
56.27	4.34	56.66	.39	2.04 PCT
57.59	5.48	57.58	-.01	-.07 PCT
58.00	6.52	58.06	.06	.29 PCT

AVERAGE OF PREDICTED - OBSERVED .19

AVERAGE OVER TOTAL CHANGE IN X 1.01 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 115
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3244	.3898	20.16 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0701	.0278	.0979

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.310	2.087

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
10.06	29.00	18.94

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.66	1.042

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
10.06	0.00	10.06	0.00	0.00 PCT
10.19	.10	10.95	.76	3.99 PCT
15.81	.81	16.15	.34	1.81 PCT
18.39	1.59	20.16	1.77	9.34 PCT
21.32	2.16	22.27	.95	5.02 PCT
23.41	2.95	24.39	.98	5.18 PCT
26.09	3.77	25.89	-.20	-1.06 PCT
26.98	5.11	27.36	.38	2.02 PCT
28.34	6.10	27.98	-.36	-1.89 PCT

AVERAGE OF PREDICTED - OBSERVED .51

AVERAGE OVER TOTAL CHANGE IN X 2.71 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 116
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3263	.3545	8.64 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0754	.0303	.1057

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.610	1.971

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
63.27	66.65	3.38

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.68	1.056

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
63.27	0.00	63.27	0.00	0.00 PCT
64.20	.60	64.16	-.04	-1.27 PCT
65.27	1.37	64.96	-.31	-9.07 PCT
65.47	2.04	65.45	-.02	-.61 PCT
65.50	2.58	65.74	.24	7.02 PCT
65.44	3.14	65.96	.52	15.47 PCT
66.18	4.24	66.26	.08	2.27 PCT
66.58	5.25	66.41	-.17	-4.90 PCT
66.58	6.38	66.52	-.06	-1.86 PCT

AVERAGE OF PREDICTED - OBSERVED .03

AVERAGE OVER TOTAL CHANGE IN X .78 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 116
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3263	.3545	8.64 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0731	.0294	.1025

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.380	2.134

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
43.08	52.50	9.42

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.68	1.056

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
43.08	0.00	43.08	0.00	0.00 PCT
44.72	.34	44.47	-.25	-2.68 PCT
46.79	.85	46.18	-.61	-6.53 PCT
48.46	1.70	48.25	-.21	-2.19 PCT
49.31	2.30	49.29	-.02	-.17 PCT
49.99	2.86	50.03	.04	.47 PCT
50.63	3.42	50.60	-.03	-.28 PCT
51.67	4.50	51.36	-.31	-3.33 PCT
51.83	5.57	51.81	-.02	-.24 PCT

AVERAGE OF PREDICTED - OBSERVED -.16

AVERAGE OVER TOTAL CHANGE IN X -1.66 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 116
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3263	.3545	8.64 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0683	.0275	.0958

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.380	2.265

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
12.33	20.07	7.74

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.68	1.056

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
12.33	0.00	12.33	0.00	0.00 PCT
14.54	.60	14.13	-.41	-5.28 PCT
15.67	1.37	15.84	.17	2.24 PCT
16.98	2.04	16.93	-.05	-.70 PCT
16.74	2.58	17.59	.85	11.02 PCT
18.62	3.14	18.14	-.48	-6.26 PCT

AVERAGE OF PREDICTED - OBSERVED .01

AVERAGE OVER TOTAL CHANGE IN X .17 PCT

NUMBER OF OBSERVATIONS 6

RUN NUMBER 117
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3350	.2825	-15.67 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0724	.0303	.1027

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
6.810	2.476

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
71.06	62.06	-9.00

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.77	1.102

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
71.06	0.00	71.06	0.00	0.00 PCT
70.80	.07	70.81	.00	.10 PCT
69.48	.50	69.41	-.07	-.73 PCT
68.21	1.00	68.07	-.14	-1.56 PCT
66.78	1.50	66.97	.19	2.11 PCT
66.04	2.00	66.07	.03	.36 PCT
65.30	2.52	65.31	.01	.14 PCT
63.83	3.56	64.20	.37	4.07 PCT
62.23	4.63	63.45	1.22	13.52 PCT

AVERAGE OF PREDICTED - OBSERVED .18

AVERAGE OVER TOTAL CHANGE IN X 2.00 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 117
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3350	.2825	-15.67 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0691	.0289	.0980

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.590	2.633

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
57.15	34.76	-22.39

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.77	1.102

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
57.15	0.00	57.15	0.00	0.00 PCT
56.21	.29	54.81	-1.40	-6.23 PCT
52.18	.73	51.73	-.45	-2.02 PCT
48.23	1.25	48.69	.46	2.04 PCT
46.42	1.79	46.11	-.31	-1.41 PCT
43.49	2.28	44.18	.69	3.08 PCT
41.71	2.90	42.20	.49	2.20 PCT
38.66	3.88	39.89	1.23	5.49 PCT
35.97	4.94	38.19	2.22	9.91 PCT

AVERAGE OF PREDICTED - OBSERVED .33

AVERAGE OVER TOTAL CHANGE IN X 1.45 PCT

NUMBER OF OBSERVATIONS 9

RUN NUMBER 117
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3350	.2825	-15.67 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0650	.0272	.0922

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.620	2.813

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
25.89	7.02	-18.87

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
2.77	1.102

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
25.89	0.00	25.89	0.00	0.00 PCT
24.70	.07	25.43	.73	3.85 PCT
22.19	.50	22.82	.63	3.33 PCT
18.64	1.00	20.25	1.61	8.51 PCT
17.14	1.50	18.09	.95	5.04 PCT
15.39	2.00	16.29	.90	4.76 PCT
15.49	2.55	14.64	-.85	-4.49 PCT
12.37	3.56	12.34	-.03	-.14 PCT
10.80	4.63	10.66	-.14	-.74 PCT
11.04	5.66	9.54	-1.50	-7.93 PCT
8.66	7.11	8.53	-.13	-.70 PCT
7.41	8.90	7.82	.41	2.16 PCT

AVERAGE OF PREDICTED - OBSERVED .21

AVERAGE OVER TOTAL CHANGE IN X 1.14 PCT

NUMBER OF OBSERVATIONS 12

RUN NUMBER 118
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3942	.4428	12.33 PCT

LB-MOLS	LB-MOLS	HOLD-UP LB-MOLS
.0689	.0329	.1018

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.540	1.733

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
62.31	66.73	4.42

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.23	1.273

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
62.31	0.00	62.31	0.00	0.00 PCT
63.97	.66	63.71	-.26	-5.89 PCT
64.88	1.22	64.54	-.34	-7.62 PCT

AVERAGE OF PREDICTED - OBSERVED -.20

AVERAGE OVER TOTAL CHANGE IN X -4.50 PCT

NUMBER OF OBSERVATIONS 3

RUN NUMBER 118
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3942	.4428	12.33 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0670	.0320	.0990

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.380	1.874

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
42.67	63.74	21.07

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.23	1.273

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
42.67	0.00	42.67	0.00	0.00 PCT
46.27	.38	46.54	.27	1.27 PCT
50.68	.97	51.18	.50	2.40 PCT

AVERAGE OF PREDICTED - OBSERVED .26

AVERAGE OVER TOTAL CHANGE IN X 1.22 PCT

NUMBER OF OBSERVATIONS 3

RUN NUMBER 119
TRAY NUMBER 1

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3969	.3240	-18.37 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0638	.0323	.0961

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
7.790	2.311

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
65.42	51.12	-14.30

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.30	1.332

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
65.42	0.00	65.42	0.00	0.00 PCT
65.10	.11	64.76	-.34	-2.41 PCT
62.20	.64	61.96	-.24	-1.68 PCT
59.55	1.23	59.52	-.03	-.23 PCT
58.00	1.91	57.38	-.62	-4.36 PCT
56.11	2.52	55.92	-.19	-1.30 PCT
54.83	3.24	54.64	-.19	-1.34 PCT
53.77	4.22	53.42	-.35	-2.43 PCT

AVERAGE OF PREDICTED - OBSERVED -.25

AVERAGE OVER TOTAL CHANGE IN X -1.72 PCT

NUMBER OF OBSERVATIONS 8

RUN NUMBER 119
TRAY NUMBER 3

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3969	.3240	-18.37 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0605	.0306	.0911

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
8.620	2.424

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
49.81	21.92	-27.89

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.30	1.332

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
49.81	0.00	49.81	0.00	0.00 PCT
46.71	.33	46.26	-.45	-1.61 PCT
41.08	.93	40.92	-.16	-.56 PCT
36.75	1.50	36.94	.19	.69 PCT
33.31	2.22	33.08	-.23	-.82 PCT
30.01	2.78	30.78	.77	2.76 PCT
28.79	3.56	28.34	-.45	-1.61 PCT

AVERAGE OF PREDICTED - OBSERVED -.05

AVERAGE OVER TOTAL CHANGE IN X -.16 PCT

NUMBER OF OBSERVATIONS 7

RUN NUMBER 119
TRAY NUMBER 5

VAPOR RATE LBMOLS/MIN	LIQUID RATE LBMOLS/MIN	CHANGE IMPOSED IN LIQUID RATE
.3969	.3240	-18.37 PCT

TRAY DECK HOLD-UP LB-MOLS	DOWNCOMER HOLD-UP LB-MOLS	TOTAL TRAY HOLD-UP LB-MOLS
.0575	.0291	.0866

TRAY RESPONSE CONSTANT PREDICTED FOR TOTAL HOLD-UP	TIME CONSTANT PREDICTED, MIN
9.790	2.617

INITIAL TRAY MOL PCT	FINAL TRAY MOL PCT	CHANGE IN TRAY MOL PCT
17.54	2.70	-14.84

SUPERFICIAL GAS VELOCITY IN BUBBLING AREA, FT/SEC	VAPOR F FACTOR FT/SEC X SQRT(LBS/FT3)
3.30	1.332

EXPERIMENTAL OBSERVATIONS

OBSERVED MOL PCT	TIME MIN	PREDICTED MOL PCT	PREDICTED VALUE - OBSERVED	ERROR OVER CHANGE IN X
17.54	0.00	17.54	0.00	0.00 PCT
14.62	.64	14.32	-.30	-2.02 PCT
11.02	1.23	11.97	.95	6.43 PCT
12.22	1.91	9.85	-2.37	-15.96 PCT
7.43	2.52	8.36	.93	6.30 PCT
6.53	3.24	7.00	.47	3.18 PCT
5.43	4.22	5.66	.23	1.54 PCT
4.93	5.51	4.51	-.42	-2.85 PCT
4.16	6.67	3.86	-.30	-2.02 PCT
3.40	7.62	3.51	.11	.72 PCT

AVERAGE OF PREDICTED - OBSERVED -.07

AVERAGE OVER TOTAL CHANGE IN X -.47 PCT

NUMBER OF OBSERVATIONS 10

APPENDIX C

FORTRAN II PROGRAM FOR THE CALCULATION OF SAMPLE PROPERTIES FROM REFRACTOMETER SCALE READING

1. LIST OF STATEMENTS

```
C  C
 100   READ69,NRUN,SAMPN,TYPE,REFSC
 69    FORMAT(I5,A5,3X,A2,F7.3)
       IF(TYPE-0.60)70,100,270
 70    A=((1.2762393E-09*REFSC-2.8123227E-07)*REFSC-2.0922072
      $E-05)*REFSC
       REFIX=(A+6.7203912E-03)*REFSC+1.2034111E-00
       B=((-1.0148081E-06*REFSC+3.9809369E-04)*REFSC-2.138159
      $9E-02)*REFSC
       XMOLP=(B-2.7003377E-00)*REFSC+1.7767899E+02
       AVGWT=7.8109999E+01-2.0029999E-01*XMOLP
       C=((-5.4176360E-10*XMOLP+1.4484733E-07)*XMOLP-1.470526
      $5E-05)*XMOLP
       D=((C+7.0927564E-04)*XMOLP-1.2958668E-02)*XMOLP
       BPNLQ=(D-5.9079956E-01)*XMOLP+1.7621361E+02
       E=((-3.3167081E-10*XMOLP+1.1395702E-07)*XMOLP-1.668715
      $2E-05)*XMOLP
       G=((E+1.4117442E-03)*XMOLP-7.5715889E-02)*XMOLP
       EYMOP=(G+3.0597979E-00)*XMOLP+2.3275131E-01
       H=(2.3193473E-08*XMOLP-8.2517482E-06)*XMOLP
       DENLQ=(H-7.0151515E-05)*XMOLP+8.1374685E-01
       O=((1.4568764E-10*XMOLP+6.8181818E-08)*XMOLP-1.6611305
      $E-05)*XMOLP
       VISL=(O-5.9032634E-05)*XMOLP+3.1907692E-01
       P=((1.3243464E-08*XMOLP-4.0419494E-06)*XMOLP+4.4868369
      $E-04)*XMOLP
       Q=((P-2.0011625E-02)*XMOLP+6.7731198E-02)*XMOLP
       DHVLQ=(Q+1.1514039E+01)*XMOLP+1.3234015E+04
       PUNCH300
 300   FORMAT(5X13HRUN SAMP TYPE2(3X3HREF)5X3HLIQ5X3HAVG4X3HL
      $IQ)
       PUNCH301
 301   FORMAT(4X2(2X2HNO)2X11HSAMP SCALE 1X5HINDEX3X20HMOL-PC
      $T MOL-WT NBP-F)
       PUNCH402,NRUN,SAMPN,TYPE,REFSC,REFIX,XMOLP,AVGWT,BPNLQ
 402   FORMAT(I7,A5,3X,A2,F8.3,F8.5,3F7.2//)
       PUNCH303
 303   FORMAT(14X6HEQ-VAP2X7HLIQ-DEN2X7HLIQ-VIS2X10HDH-VAP-NB
      $P)
       PUNCH304
 304   FORMAT(14X7HMOL-PCT1X7HG/M-NBP3X6HCP-NBP2X10HBTU/LB-MO
      $L)
       PUNCH305,EYMOP,DENLQ,VISL,DHVLQ
 305   FORMAT(F20.2,F9.4,F8.3,F12.2//)
```

```
      GOTO100
270   AA=((1.2762393E-09*REFSC-2.8123227E-07)*REFSC-2.092207
     $2E-05)*REFSC
      REFIX=(AA+6.7203912E-03)*REFSC+1.2034111E-00
      BB=((-1.0148081E-06*REFSC+3.9809369E-04)*REFSC-2.13815
     $99E-02)*REFSC
      YMOLP=(BB-2.7003377E-00)*REFSC+1.7767899E+02
      AVGWT=7.8109999E+01-2.0029999E-01*YMOLP
      CC=((-1.2235940E-09*YMOLP+3.3672270E-07)*YMOLP-3.36728
     $07E-05)*YMOLP
      DD=((CC+1.5170742E-03)*YMOLP-3.3909358E-02)*YMOLP
      EBPNL= (DD+2.6462801E-02)*YMOLP+1.7611349E+02
      EE=((8.3597195E-10*YMOLP-2.5483473E-07)*YMOLP+2.754147
     $7E-05)*YMOLP
      GG=((EE-1.2418429E-03)*YMOLP+2.8621176E-02)*YMOLP
      EXMOP=(GG+1.3752741E-01)*YMOLP+7.1358492E-02
      HH=((2.3193473E-08*EXMOP-8.2517482E-06)*EXMOP-7.015151
     $5E-05)*EXMOP
      EDENL=HH+8.1374685E-01
      OO=((1.4568764E-10*EXMOP+6.8181818E-08)*EXMOP-1.661130
     $5E-05)*EXMOP
      EVISL=(OO-5.9032634E-05)*EXMOP+3.1907692E-01
      PP=((1.3243464E-08*EXMOP-4.0419494E-06)*EXMOP+4.486836
     $9E-04)*EXMOP
      QQ=((PP-2.0011625E-02)*EXMOP+6.7731198E-02)*EXMOP
      EDHVL=(QQ+1.1514039E+01)*EXMOP+1.3234015E+04
      PUNCH400
400   FORMAT(5X13HRUN SAMP TYPE2(3X3HREF)5X5HVAPOR3X3HAVG3X6
     $HEQ-LIQ)
      PUNCH401
401   FORMAT(4X2(2X2HNO)2X10HSAMP SCALE2X5HINDEX3X7HMOL-PCT1
     $X6HMOL-WT1X5HNBP-F)
      PUNCH402,NRUN,SAMPN,TYPE,REFSC,REFIX,YMOLP,AVGWT,EBPNL
      PUNCH403
403   FORMAT(12X2(2X6HEQ-LIQ)1X14HDEN EQ-LIQ VIS1X12HEQ-LIQ
     $DHVAP)
      PUNCH404
404   FORMAT(14X7HMOL-PCT2X9HG/M - NBP2X8HCP - NBP2X10HBTU/L
     $B-MOL)
      PUNCH405,EXMOP,EDENL,EVISL,EDHVL
405   FORMAT(F20.2,F10.4,F10.3,F18.2//)
      GOTO100
      END
```

2. DEFINITION OF VARIABLES USED IN STATEMENTS

AVGWT=AVERAGE MOL WT OF THE SAMPLE
BPNLQ= NORMAL BOILING POINT IN DEGREES F OF LIQUID SAMPLE
DENLQ=LIQUID SAMPLE DENSITY IN GM/ML
DHVLQ=INTEGRAL ISOBARIC HEAT OF VAPORIZATION OF THE LIQUID SAMPLE, BTU/LB-MOL

EBPNL=NORMAL BOILING POINT IN DEGREES F OF LIQUID IN EQUILIBRIUM WITH VAPOR SAMPLE
EDENL=DENSITY OF LIQUID IN EQUILIBRIUM WITH VAPOR SAMPLE, GM/ML
EDHVL=INTEGRAL ISOBARIC HEAT OF VAPORIZATION OF THE LIQUID IN EQUILIBRIUM WITH VAPOR SAMPLE
EXMOP=MOL PCT OF ACETONE IN LIQUID IN EQUILIBRIUM WITH VAPOR SAMPLE
EYMOP=MOL PCT OF ACETONE IN VAPOR IN EQUILIBRIUM WITH LIQUID SAMPLE
NRUN=RUN NUMBER
REFSC=REFRACTOMETER SCALE READING
REFIX=REFRACTIVE INDEX
SAMPN=SAMPLE NUMBER
TYPE=SAMPLE TYPE - LIQUID OR VAPOR, I.E., L OR V
XMOLP=MOL PCT OF ACETONE IN LIQUID SAMPLE
YMOLP=MOL PCT OF ACETONE IN VAPOR SAMPLE

3. TYPICAL PRINT-OUT OF COMPUTER

RUN NO	SAMP NO	TYPE SAMP	REF SCALE	REF INDEX	LIQ MOL-PCT	AVG MOL-WT	LIQ NBP-F
31	1L	L	32.370	1.39089	80.25	62.03	139.41

EQ-VAP MOL-PCT	LIQ-DEN G/M-NBP	LIQ-VIS CP-NBP	DH-VAP-NBP BTU/LB-MOL
86.38	.7669	.248	12945.15

RUN NO	SAMP NO	TYPE SAMP	REF SCALE	REF INDEX	VAPOR MOL-PCT	AVG MOL-WT	EQ-LIQ NBP-F
31	5V	V	37.745	1.41473	64.64	65.16	148.74

EQ-LIQ MOL-PCT	EQ-LIQ DEN G/M - NBP	EQ-LIQ VIS CP - NBP	EQ-LIQ DHVAP BTU/LB-MOL
47.37	.7943	.286	13249.02

IN THE ABOVE PRINT-OUT
LIQ NBP-F = LIQUID NORMAL BOILING POINT IN DEGREES F
EQ-VAP MOL-PCT = COMPOSITION OF THE VAPOR IN EQUILIBRIUM WITH THE LIQUID SAMPLE
LIQ-DEN G/M-NBP = LIQUID DENSITY IN GM/ML AT NBP
LIQ-VIS CP-NBP = LIQUID VISCOSITY IN CENTIPOISES AT THE NORMAL BOILING POINT
DH-VAP-NBP BTU/LB-MOL = INTEGRAL ISOBARIC HEAT OF VAPORIZATION OF LIQUID MIXTURE
ABOVE SYMBOLS PRECEDED BY EQ IMPLIES THE SAME PROPERTY FOR THE LIQUID IN EQUILIBRIUM WITH A VAPOR SAMPLE

APPENDIX D

A FORGO PROGRAM FOR THE CALCULATION OF COLUMN OPERATING CONDITIONS

1. LIST OF STATEMENTS

```
C   C   CALCULATION OF COLUMN OPERATING CONDITIONS
 700    READ69,NRUN,TIME,DTFCW,CWIHG,NROT,TRREL,COMR,RROT,T1CO
      $N,RRVAP
        READ70,T1COV,COMRE,REBCM,TRSCR,TMCOM,TDPHO,TEFFA,HOLER
      $,HOLEN
        READ71,TMAGR,WEIRH,DCHUP,SBK,TBCOM
  69    FORMAT(I6,A4,F5.1,F5.2,I5,F5.1,4F5.2)
  70    FORMAT(3F5.2,F5.1,3F5.2,F5.3,F5.0)
  71    FORMAT(F5.2,F5.1,F5.2,F5.3,F5.2)
        A=((-1.3770130E-03*CWIHG+8.9238155E-02)*CWIHG-2.386782
      $2E-00)
        CWFR=(A*CWIHG+4.5336202E+01)*CWIHG+9.1168493E+01
        CWQR=CWFR*DTFCW*1.0
        TTREL= (-4.2847250E-05*TRREL+1.0138606E-00)*TRREL -1.8
      $465462E-00
        IF(TTREL-73.)80,81,81
  80    DENR=(-2.0396270E-06*COMR-6.5058275E-04)*COMR+8.781496
      $5E-01
        GO TO 100
  81    IF(TTREL-82.)82,83,83
  82    DENR=(-2.1223776E-06*COMR-6.4003496E-04)*COMR+8.724482
      $5E-01
        GO TO 100
  83    IF(TTREL-91.)84,85,85
  84    CC=((-1.4763014E-08*COMR+1.7365967E-07)*COMR-7.3718337
      $E-04)
        DENR=(CC*COMR)+8.6791118E-01
        GO TO 100
  85    IF(TTREL-100.)86,87,87
  86    DD=((-1.3209013E-08*COMR+1.2004662E-07)*COMR-7.8987956
      $E-04)
        DENR=(DD*COMR)+8.6430629E-01
        GO TO 100
  87    IF(TTREL-109.)88,89,89
  88    DENR=(-1.9510489E-06*COMR-6.9925874E-04)*COMR+8.567643
      $3E-01
        GO TO 100
  89    IF(TTREL-118.)90,91,91
  90    DENR=(-1.6759906E-06*COMR-7.1785547E-04)*COMR+8.507860
      $1E-01
        GO TO 100
  91    IF(TTREL-125.)92,93,93
```

```
92    DENR=(-1.6631701E-06*COMR-7.2177389E-04)*COMR+8.462188
     $8E-01
      GO TO 100
93    IF(TTREL-132.)94,95,95
94    EE=((-1.2781662E-08*COMR+4.6969696E-07)*COMR-8.3181041
     $E-04)
      DENR=(EE*COMR)+8.4292517E-01
      GO TO 100
95    GG=((2.3193473E-08*COMR-8.2517482E-06)*COMR-7.0151515E
     $-05)
      DENR=(GG*COMR)+8.1374685E-01
100   IF(NROT-2)110,120,130
110   RREGM=(0.620/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RROT/100
     $.)
      GO TO 200
120   RREGM=(2.70/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RROT/100.
     $)
      GO TO 200
130   RREGM=(7.50/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RROT/100.
     $)
200   AGWTR=7.8109999E+01-2.0029999E-01*COMR
      RRLMM=RREGM*DENR*8.345*1./AGWTR
201   A=((-5.4176360E-10*COMR+1.448473E-07)*COMR-1.4705265E-
     $05)*COMR
      B=((A+7.0927564E-04)*COMR-1.2958668E-02)*COMR-5.907995
     $6E-01
      RNBP=(B*COMR)+1.7621361E+02
      DTBAR=RNBP-TTREL
      C=((2.8787878E-06*COMR-1.7878787E-04)*COMR-5.5590909E-
     $02)
      CPRBP=(C*COMR)+3.6228181E+01
      IF(TTREL-95.)269,270,270
269   D=((3.9257964E-06*COMR-2.6229603E-04)*COMR-2.9419968E-
     $02)
      CPRTT=(D*COMR)+3.2353986E+01
      GO TO 300
270   IF(TTREL-113.)271,272,272
271   CPRTT=(1.8496503E-04*COMR-3.9323776E-02)*COMR+3.309426
     $5E+01
      GO TO 300
272   IF(TTREL-131.)273,274,274
273   CPRTT=(1.5314685E-04*COMR-3.9987412E-02)*COMR+3.387881
     $1E+01
      GO TO 300
274   IF(TTREL-149.)275,276,276
275   CPRTT=(1.4090909E-04*COMR-4.1536363E-02)*COMR+3.472999
     $9E+01
      GO TO 300
276   PRINT277
277   FORMAT (10X21H REFLUX TEMP TOO HIGH)
300   CPAVR=(CPRTT+CPRBP)/2.0
      E=((1.3243464E-08*TICON-4.0419494E-06)*TICON+4.4868369
     $E-04)*TICON
      QREB=CPAVR*DTBAR*RRLMM
```

```
      G=((E-2.0011625E-02)*TICON+6.7731198E-02)*TICON
      DHCON=(G+1.1514039E+01)*TICON+1.3234015E+04
      DREFI=QREB/DHCON
      RRILM=DREFI+RRLMM
      IF(NROT-2)410,420,430
410   RGPMV=(0.620/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RRVAP/10
     $0.)
      GO TO 500
420   RGPMV=(2.70/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RRVAP/100
     $.)
      GO TO 500
430   RGPMV=(7.50/SQRTF(7.02*(DENR)/(8.02-DENR)))*(RRVAP/100
     $.)
500   RRVLM=RGPMV*DENR*8.345*1./AGWTR
      QREBV=CPAVR*DTBAR*RRVLM
      H=((1.3243464E-08*TICOV-4.0419494E-06)*TICOV+4.4868369
     $E-04)*TICON
      O=((H-2.0011625E-02)*TICOV+6.7731198E-02)*TICOV
      QVCON=(O+1.1514039E+01)*TICOV+1.3234015E+04
      DREIV=QREBV/QVCON
      RRIVA=DREIV+RRVLM
      P=((-3.3167081E-10*COMRE+1.1395702E-07)*COMRE-1.668715
     $2E-05)*COMRE
      Q=((P+1.4117442E-03)*COMRE-7.5715889E-02)*COMRE
      EVREB=(Q+3.0597979E-00)*COMRE+2.3275131E-01
      R=((1.3243464E-08*EVREB-4.0419494E-06)*EVREB+4.4868369
     $E-04)*EVREB
      S=((R-2.0011625E-02)*EVREB+6.7731198E-02)*EVREB
      DHVAR=(S+1.1514039E+01)*EVREB+1.3234015E+04
      QREBO=DHVAR*RRIVA
      T=((-2.1443106E-06*REBCM+3.8284334E-04)*REBCM+1.403552
     $7E-01)
      REBHU=T*REBCM+1.0283381E-00
      REBGA=7.48*REBHU
      TTSCR= (-4.2847250E-05*TRSCR+1.0138606E-00)*TRSCR -1.8
     $465462E-00
      U=((1.3243464E-08*COMR-4.0419494E-06)*COMR+4.4868369E-
     $04)*COMR
      V=((U-2.0011625E-02)*COMR+6.7731198E-02)*COMR
      DHRCO=(V+1.1514039E+01)*COMR+1.3234015E+04
      DTSCR=RNBP-TTSCR
      QOHCO=DTSCR*CPAVR*RRLMM+RRLMM*DHRCO
      VARIN=QOHCO/DHRCO
      W=((-5.4176360E-10*TMCOM+1.4484733E-07)*TMCOM-1.470526
     $5E-05)*TMCOM
      X=((W+7.0927564E-04)*TMCOM-1.2958668E-02)*TMCOM
      TMNBP=(X-5.9079956E-01)*TMCOM+1.7621361E+02
      Y=((2.3193473E-08*TMCOM-8.2517482E-06)*TMCOM-7.0151515
     $E-05)*TMCOM
      TMDEN =Y+8.1374685E-01
      RHOMT=TMDEN*62.4
      TMPRE=14.7+(TDPHO/12.0)*.433
      VOLRA=RRIVA*359.*(14.7/TMPRE)*((TMNBP+460.)/492.)*(1./
     $60.)
```

```
      Z=((-3.3167081E-10*TMCOM+1.1395702E-07)*TMCOM-1.668715
     $2E-05)*TMCOM
      AA=((Z+1.4117442E-03)*TMCOM-7.5715889E-02)*TMCOM
      TMEVA=(AA+3.0597979E-00)*TMCOM+2.3275131E-01
      TMAVA=TMCOM+((TMEVA-TMCOM)*TEFFA)/100.
      AVWTV=7.8109999E+01-2.0029999E-01*TMCOM
      DENVA=AVWTV/(359.*(14.7/TMPRE)*((TMNBP+460.)/492.))
      SUPVV=VOLRA/(20.*8./144.)
      THOAR=(HOLEN*3.14*HOLER**2)/144.
      DTPD=((VOLRA/(THOAR*1.987))**2)*(DENVA/RHOMT)
      ATPD=TMAGR/TMDEN
      ELDT=(TMAGR/TMDEN)-DTPD
      TMMWT=7.8109999E+01-2.0029999E-01*TMCOM
      TMGPM=(RRILM*TMMWT/RHOMT)*7.48
      VUNL=RRILM/RRIVA
      GPMFT=TMGPM/0.6667
      UE=SBK*((RHOMT-DENVA)/DENVA)**.3333
      SBAVV=UE*THOAR
      PCTSB=(VOLRA/SBAVV)*100.
      ACTOR=(VOLRA/(0.66667*1.33333))*SQRTF(DENVA)
      TTCOM = T1CON
      ZC=1.65+0.19*WEIRH-0.65*ACTOR+0.020*GPMFT
      THU=ZC*8.*16.*1./1728.
      DCHU=(8.*2.*DCHUP/1728.)
      TTHU=THU+DCHU
      TTRET=TTHU/(RRILM*TMMWT*(1./RHOMT))
      DIMEN=REBHU/TTHU
      TDHUM=THU*RHOMT*1./TMMWT
      TTHUM=TTHU*RHOMT*1./TMMWT
      UG=VOLRA/(16.*8./144.)
      ATRHO=(2.3193473E-08*TTCOM-8.2517482E-06)*TTCOM
      TTRHO=(ATRHO-7.0151515E-05)*TTCOM+8.1374685E-01
      ABRHO=(2.3193473E-08*TBCOM-8.2517482E-06)*TBCOM
      TBRHO=(ABRHO-7.0151515E-05)*TBCOM+8.1374685E-01
      TTWT=-2.0029999E-01*TTCOM+7.8109999E+01
      TBWT=-2.0029999E-01*TBCOM+7.8109999E+01
      TTHUD=THU*TTRHO*62.4*1./TTWT
      TTHUT=TTHU*TTRHO*62.4*1./TTWT
      TBHUD=THU*TBRHO*62.4*1./TBWT
      TBHUT=TTHU*TBRHO*62.4*1./TBWT
      TDRT = ((THU*7.48)/TMGPM)*60.
      PUNCH1000,NRUN
 1000 FORMAT(21X6HRUN NO.I5)
      PUNCH1001,TIME
 1001 FORMAT(9X36HTIME FOR WHICH CALCULATIONS ARE MADE.A4//)
      PUNCH1002
 1002 FORMAT(1X19HREFLUX  INFORMATION//)
      PUNCH1003
 1003 FORMAT(5X16HREFLUX ROTAMETER2X9HROTAMETER2X19HDENSITY
     $OF   REFLUX)
      PUNCH1004
 1004 FORMAT(7X7HIN  USE9X7HREADING3X12HREFLUX GM/ML2X7HNBP
     $(F))
      PUNCH1005,NROT,RROT,DENR,RNBP
```

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1005 FORMAT(111,F18.2,F12.4,F12.1//)
     PUNCH1006
1006 FORMAT(5X15HEXTERNAL REFLUX2(3X6HREFLUX)1X20HAVG  EXTE
    $RNAL REFLUX)
     PUNCH1007
1007 FORMAT(6X4HRATE2X3HGPM8X7HMOL PCT3X6HMOL WT6X13HIN LBM
    $OLS/MIN)
     PUNCH1008,RREGM,COMR,AGWTR,RRLMM
1008 FORMAT(F13.3,F16.2,F10.2,F16.4//)
     PUNCH1009
1009 FORMAT(5X13HDELTA TEMP TO3X16HHEAT CAPACITY OF4X13HBTU
    $/MIN TO UP)
     PUNCH1010
1010 FORMAT(5X13HREFLUX NBP(F)3X33HREFLUX BTU/LBMOL-F  REFL
    $UX TO NBP)
     PUNCH 1011,DTBAR,CPAVR,QREB
1011 FORMAT(F13.2,F19.3,F21.2//)
     PUNCH1012
1012 FORMAT(5X17HINTERNAL INCREASE6X15HINTERNAL REFLUX)
     PUNCH1013
1013 FORMAT(5X19HIN REFLUX LBMOL/MIN4X15HRATE LBMOLS/MIN)
     PUNCH1014,DREFI,RRILM
1014 FORMAT(F16.4,F24.4//)
     PUNCH1015
1015 FORMAT(1X17HVAPOR INFORMATION//)
     PUNCH1016
1016 FORMAT(5X17HROTAMETER READING2X10HEQUIVALENT2X10HEQUIV
    $ALENT)
     PUNCH1017
1017 FORMAT(5X15HUSED  AS  BASIS7X3HGPM6X11HLB-MOLS/MIN)
     PUNCH1018,RRVAP,RGPMV,RRVLM
1018 FORMAT(F15.2,F16.3,F13.4//)
     PUNCH1019
1019 FORMAT(5X13HBTU/MIN TO UP5X17HINTERNAL INCREASE4X13HRA
    $TE BASED ON)
     PUNCH1020
1020 FORMAT(7X7HTO  NBP11X11HLB-MOLS/MIN6X16HREFLUX-LBMOL/M
    $IN)
     PUNCH1021,QREBV,DREIV,RRIVA
1021 FORMAT(F15.2,F20.4,F19.4//)
     PUNCH1022
1022 FORMAT(5X51HINTERNAL LIQ RATE OVER INTERNAL VAPOR RATE
    $  LMM/LMM)
     PUNCH 1023,VUNL
1023 FORMAT(20XF10.4//)
     PUNCH1027
1027 FORMAT(1X23HMIDDLE TRAY INFORMATION//)
     PUNCH1028
1028 FORMAT(1X3(3X8HTRAY LIQ)4X9HOPERATING3X8HLIQ COMP)
     PUNCH1029
1029 FORMAT(5X7HNBP (F)3X9HDEN GM/ML2X10HDEN LB/FT34X3HPSI7
    $X7HMOL PCT)
     PUNCH1030,TMNBP,TMDEN,RHOMT,TMPRE,TMCOM
1030 FORMAT(F12.1,F10.4,F13.4,F9.2,F12.2//)
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      PUNCH1031
1031 FORMAT(4X14H VAPOR LEAVING2X10HDENSITY OF5X11HSUPERFIC
     $IAL)
      PUNCH1032
1032 FORMAT(5X12HTRAY FT3/SEC3X13HVAPOR LBS/FT32X12HVAPOR F
     $T/SEC)
      PUNCH1033,VOLRA,DENVA,SUPVV
1033 FORMAT(F14.3,F16.6,F13.3//)
      PUNCH1034
1034 FORMAT(5X9HTRAY HOLE3X22HDRY-TRAY PRESSURE DROP4X13HAC
     $T TRAY PRES)
      PUNCH1035
1035 FORMAT(5X8HAREA FT24X21HIN INCHES OF TRAY LIQ5X14HDROP
     $ - IN. LIQ)
      PUNCH1036,THOAR,DTPD,ATPD
1036 FORMAT(F13.5,F18.4,F22.4//)
      PUNCH1037
1037 FORMAT(5X15HEFFECTIVE DEPTH5X9HTRAY HOLD3X9HDOWNCOMERI
     $X4HHOLD)
      PUNCH1038
1038 FORMAT(5X18HOF TRAY LIQ INCHES2X6HUP FT36X2HUP3X3HFT3)
      PUNCH1039,ELDT,THU,DCHU
1039 FORMAT(F14.2,F19.5,F12.5//)
      PUNCH1040
1040 FORMAT(5X10HTOTAL TRAY3X37HTOTAL TRAY RESIDENCE REBOIL
     $ER HOLD-UP)
      PUNCH1041
1041 FORMAT(5X11HHOLD-UP FT33X16HTIME  IN MINUTES4X16HOVER
     $TOT TRAY HU)
      PUNCH 1042,TTHU,TTRET,DIMEN
1042 FORMAT(F14.5,F17.4,F18.1//)
      PUNCH1071
1071 FORMAT(5X10HTOTAL TRAY4X9HTRAY DECK)
      PUNCH1072
1072 FORMAT(1X2(4X10HHU IN MOLS) )
      PUNCH1073,TTHUM,TDHUM
1073 FORMAT(F14.5,F14.5//)
      PUNCH1043
1043 FORMAT(5X13H    ELD      6X15HPCT THAT ACTUAL5X7HLIQ A
     $VG)
      PUNCH 1044
1044 FORMAT(5X15HALLOWABLE VAPOR3X15H     RATE      6X6HMOL
     $ WT)
      PUNCH1045
1045 FORMAT(5X15H RATE FT3/SEC  5X15H IS  OF  ELD   )
      PUNCH 1046,SBAVV,PCTSB,TMMWT
1046 FORMAT(F14.3,F19.2,F16.2//)
      PUNCH1047
1047 FORMAT(5X11HLIQUID RATE8X14HVAPOR F FACTOR4X11HLIQ RAT
     $E IN)
      PUNCH1048
1048 FORMAT(8X3HGPM11X18H(FT/SEC)SQRTLB/FT32X11HGPM/WEIR-FT
     $)
      PUNCH1049,TMGPM,ACTOR,GPMFT
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1049 FORMAT(F14.3,F20.3,F16.3//)
     PUNCH1111,TDRT
1111 FORMAT(5X31HTRAY DECK RESIDENCE TIME IN SEC4XF6.3//)
     PUNCH1113,UG
1113 FORMAT(5X44HSUPERFICIAL GAS VEL IN 16 BY 8 AREA   FT/S
    $ECF8.3//)
     PUNCH1269
1269 FORMAT(1X16HTOP TRAY HOLD-UP//)
     PUNCH1270,TTHUD
1270 FORMAT(5X31HTOP TRAY DECK HOLD-UP   LB-MOLS,F7.4//)
     PUNCH1271,TTHUT
1271 FORMAT(5X31HTOP TRAY TOTAL HOLD-UP  LB-MOLS,F7.4//)
     PUNCH1272
1272 FORMAT(1X19HBOTTOM TRAY HOLD-UP//)
     PUNCH1273,TBHUD
1273 FORMAT(5X34HBOTTOM TRAY DECK HOLD-1P   LB-MOLS,F8.4//)
     PUNCH1274,TBHUT
1274 FORMAT(5X34HBOTTOM TRAY TOTAL HOLD-UP  LB-MOLS,F8.4//)
     PUNCH1050
1050 FORMAT(1X30HOVERHEAD CONDENSER INFORMATION//)
     PUNCH1051
1051 FORMAT(5X13HCOOLING WATER4X13HCOOLING WATER4X16HHEAT A
    $BSORBED BY)
     PUNCH1052
1052 FORMAT(5X11HDELTA T (F)5X13HRATE  LBS/MIN5X12HCW   BTU
    $/MIN)
     PUNCH1053,DTFCW,CWFR,CWQR
1053 FORMAT(F13.1,F18.1,F18.1//)
     PUNCH1054
1054 FORMAT(5X13HDELTA TEMP BY7X12HHEAT REMOVED)
     PUNCH1055
1055 FORMAT(5X15HWHICH REFLUX IS5X16HFROM VAPOR BY OH)
     PUNCH1056
1056 FORMAT(5X14HSUB-COOLED (F)6X17HCONDENSER BTU/MIN)
     PUNCH1057,DTSCR,QOHCO
1057 FORMAT(F13.2,F23.2//)
     PUNCH1058
1058 FORMAT(1X20HREBOILER INFORMATION//)
     PUNCH1059
1059 FORMAT(5X18HHEAT INTO REBOILER1X2(4X8HREBOILER))
     PUNCH1060
1060 FORMAT(4X20H(BASED ON VAPOR RATE1X2(4X7HHOLD-UP))
     PUNCH1061
1061 FORMAT(5X20HFROM REFLUX) BTU/MIN5X3HFT39X4HGALS)
     PUNCH1062,QREBO,REBHU,REBGA
1062 FORMAT(F15.1,F20.2,F12.3//)
     PUNCH1074
1074 FORMAT(1X25HDATA USED IN CALCULATIONS)
     PUNCH19,NRUN,TIME,DTFCW,CWIHG,NROT,TRREL,COMR,RROT,TIC
    $ON,RRVAP
19   FORMAT(5X,I6,A4,F5.1,F5.2,I5,F5.1,4F5.2)
     PUNCH20,TICOV,COMRE,REBCM,TRSCR,TMCOM,TDPHO,TEFFA,HOLE
    $R,HOLEN
20   FORMAT(5X,3F5.2,F5.1,3F5.2,F5.3,F5.0)
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      PUNCH21,TMAGR,WEIRH,DCHUP,SBK,TBCOM
 21   FORMAT(5X,F5.2,F5.1,F5.2,F5.3,F5.2)
      PUNCH 1063
 1063 FORMAT(1H1)
      GOTO700
      END
```

2. DEFINITION OF VARIABLES USED IN STATEMENTS

ACTOR=F FACTOR, (FT/SEC)SQRT(LB/FT3)
AGWTR=REFLUX AVERAGE MOL WT
ATPD=ACTUAL OPERATING TRAY PRESSURE DROP, INCHES OF TRAY LIQUID
AVWTV=AVERAGE MOL WT OF TMAVA
COMR=REFLUX COMPOSITION, MOL PERCENT
COMRE=REBOILER COMPOSITION AT TIME OF VAPOR RATE CALCULATION, MOL PERCENT
CPAVR=AVERAGE HEAT CAPACITY OF THE REFLUX BETWEEN THE ACTUAL TEMPERATURE AND THE NORMAL BOILING POINT, BTU/(LBMOL-F)
CPRBP=HEAT CAPACITY OF THE REFLUX AT THE NORMAL BOILING POINT, BTU/(LBMOL-F)
CPRTT=HEAT CAPACITY OF THE REFLUX AT REFLUX TEMPERATURE, BTU/(LBMOL-F)
CWFR=COOLING WATER FLOWRATE, LBS/MIN
CWIHG=COOLING WATER MANOMETER READING, INCH MERCURY
CWQR=HEAT REMOVED BY COOLING WATER, BTU/MIN
DCHU=DOWNCOMER HOLD-UP, FT3
DCHUP=DOWNCOMER LIQUID HEIGHT, INCHES
DENR=SPECIFIC GRAVITY OF THE REFLUX
DENVA=VAPOR DENSITY AT MIDDLE TRAY, LBS/FT3
DHCON=HEAT OF CONDENSATION OF THE VAPOR ENTERING THE TOP TRAY, BTU/LBMOL
DHRCO=HEAT OF CONDENSATION OF REFLUX IN OVERHEAD CONDENSER, BTU/LBMOL
DIMEN=REBOILER HOLD-UP/TOTAL TRAY HOLD-UP
DREIV=INCREASE IN INTERNAL REFLUX IN VAPOR CALCULATION LBMOLS/MIN
DREFI=INTERNAL INCREASE IN REFLUX FLOW RATE, LBMOL/MIN
DTBAR=AMOUNT BY WHICH REFLUX IS SUBCOOLED, DEGREES F
DTFCW=DELTA IN COOLING WATER TEMPERATURE THROUGH THE OVERHEAD CONDENSER, DEGREES F
DTPD=DRY TRAY PRESSURE DROP, INCHES OF TRAY LIQUID
DTSCR=DELTA TEMPERATURE BY WHICH THE REFLUX IS SUB-COOLED IN THE OVERHEAD CONDENSER, DEGREES F
ELDT=EFFECTIVE DEPTH OF LIQUID ON A TRAY, INCHES
EVREB=VAPOR IN EQUILIBRIUM WITH COMRE, MOL PERCENT
GPMFT=LIQUID RATE ON MIDDLE TRAY, GPM/FT OF WEIR
HOLEN=NUMBER OF HOLES PER TRAY
HOLER=PERFORATION RADIUS, INCHES

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NRUN=RUN NUMBER
NROT=NUMBER OF THE ROTAMETER IN USE
PCTSB=PERCENT THAT ACTUAL VAPOR RATE IS OF SBAVV RATE
QOHCO=HEAT REMOVED FROM THE VAPORS IN THE OVERHEAD
 CONDENSER, BTU/MIN
QREB=HEAT NECESSARY TO RAISE REFLUX TO THE NORMAL
 BOILING POINT, BTU/MIN
QREBO=HEAT INPUT TO REBOILER, BTU/MIN
QREBV=HEAT NECESSARY TO RAISE THE REFLUX TO THE
 NORMAL  BOILING POINT IN VAPOR CALCULATION, BTU/MIN
QVCON=HEAT OF CONDENSATION OF THE VAPOR ENTERING THE
 TOP TRAY IN THE VAPOR CALCULATION, BTU/LBMOL
REBCM=REBOILER LIQUID LEVEL
REBGA=REBOILER HOLD-UP IN GALLONS
REBHU=REBOILER HOLD-UP IN FT3
RGPMV=REFLUX RATE ON WHICH VAPOR RATE BASED, GPM
RHOMT=MIDDLE TRAY LIQUID DENSITY, LBS/FT3
RNBP=NORMAL BOILING POINT OF THE REFLUX
RREGM=REFLUX FLOW RATE TO COLUMN, GPM
RRILM=INTERNAL REFLUX RATE, LBMOLS/MIN
RRIVA=INTERNAL REFLUX RATE ON WHICH VAPOR RATE IS
 BASED, LBMOLS/MIN
RRLMM=EXTERNAL REFLUX FLOW RATE, LBMOLS/MIN
RROT=ROTAMETER READING ON WHICH REFLUX BASED, PERCENT
RRVAP=REFLUX ROTAMETER READING ON WHICH VAPOR RATE IS
 BASED, PERCENT
RRVLM=REFLUX RATE ON WHICH VAPOR RATE BASED, LBMOL/MIN
SBAVV=ELD ALLOWABLE VAPOR RATE, FT3/SEC
SBK=CE FACTOR IN ELD JETTING EQUATION
SUPVV=SUPERFICIAL VAPOR VELOCITY BASED ON ENTIRE
 COLUMN CROSS SECTION, FT/SEC
T1COV=COMPOSITION OF THE VAPOR ENTERING THE TOP TRAY
 IN THE VAPOR CALCULATION, MOL PERCENT
T1CON=COMPOSITION OF THE VAPOR ENTERING THE TOP TRAY
TBCOM=BOTTOM TRAY LIQUID COMPOSITION, MOL PERCENT
TBHUD=BOTTOM TRAY DECK HOLD-UP, LB-MOLS
TBHUT=BOTTOM TRAY TOTAL HOLD-UP, LB-MOLS
TBRHO=BOTTOM TRAY LIQUID SPECIFIC GRAVITY
TBWT=BOTTOM TRAY AVERAGE MOL WT FOR LIQUID PHASE
TDHUM=MIDDLE TRAY DECK HOLD-UP, LBMOLS
TDPHO=PRESSURE DROP FROM OVERHEAD CONDENSER TO THE
 MIDDLE TRAY, INCHES OF WATER
TDRT=MIDDLE TRAY DECK RESIDENCE TIME, SECONDS
TEFFA=ASSUMED TRAY EFFICIENCY
TIME=TIME FOR WHICH THE CALCULATIONS ARE MADE, MINUTES
THOAR=TRAY PERFORATION AREA, FT2
THU=TRAY DECK HOLD-UP, FT3
TMAGR=ACTUAL OPERATING TRAY PRESSURE DROP, INCHES OF
 WATER
TMAVA=ACTUAL COMPOSITION OF THE VAPOR LEAVING THE
 MIDDLE TRAY, MOL PERCENT
TMCOM=MIDDLE TRAY LIQUID COMPOSITION, MOL PERCENT
TMDEN=MIDDLE TRAY SPECIFIC GRAVITY FOR LIQUID PHASE
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TMEVA=VAPOR IN EQUILIBRIUM WITH MIDDLE TRAY LIQUID, MOL PERCENT
TMGPM=MIDDLE TRAY LIQUID RATE, GPM
TMMWT=AVERAGE MOL WT OF MIDDLE TRAY LIQUID
TMPRE=MIDDLE TRAY OPERATING PRESSURE, PSI
TRREL=RECORDED REFLUX TEMPERATURE, DEGREES F
TRSCR=RECORDED TEMPERATURE TO WHICH REFLUX IS SUBCOOLED IN OVERHEAD CONDENSER, DEGREES F
TTCOM=TOP TRAY LIQUID COMPOSITION, MOL PERCENT
TTHU=TOTAL TRAY HOLD-UP, FT3
TTHUD=TOP TRAY DECK HOLD-UP, LB-MOLS
TTHUM=MIDDLE TRAY TOTAL HOLD-UP, LBMOLS
TTHUT=TOP TRAY TOTAL HOLD-UP, LB-MOLS
TTREL=TRUE REFLUX TEMPERATURE, DEGREES F
TTRET=TOTAL TRAY RESIDENCE TIME, MINUTES
TTRHO=TOP TRAY LIQUID SPECIFIC GRAVITY
TTSCR=TRUE VALUE OF TRSCR
TTWT=TOP TRAY AVERAGE MOL WT FOR LIQUID PHASE
UE=ELD ALLOWABLE VAPOR VELOCITY THROUGH PERFORATIONS, FT/SEC
UG=SUPERFICIAL GAS VELOCITY BASED ON BUBBLING AREA
VARIN=INTERNAL VAPOR RATE BASED ON EXTERNAL REFLUX RATE (ONLY CORRECT AT TOTAL REFLUX), LBMOLS/MIN
VOLRA=VAPOR FLOW RATE AT THE MIDDLE TRAY, FT3/SEC
VUNL=LIQUID RATE/VAPOR RATE
WEIRH=WEIR HEIGHT, INCHES

3. TYPICAL COMPUTER PRINT-OUT

RUN NO 117
TIME FOR WHICH CALCULATIONS ARE MADE 3.0

REFLUX INFORMATION

REFLUX ROTAMETER IN USE	ROTAMETER READING	DENSITY OF REFLUX GM/ML	REFLUX NBP (F)
3	30.00	.7806	139.9

EXTERNAL REFLUX RATE GPM	REFLUX MOL PCT	REFLUX AVG MOL WT	EXTERNAL REFLUX IN LBMOLS/MIN
2.586	77.20	62.65	.2689

DELTA TEMP TO REFLUX NBP(F)	HEAT CAPACITY OF REFLUX BTU/LBMOL-F	BTU/MIN TO UP REFLUX TO NBP
20.69	31.950	177.72

INTERNAL INCREASE IN REFLUX LBMOL/MIN	INTERNAL REFLUX RATE LBMOLS/MIN
.0136	.2825

VAPOR INFORMATION

ROTAMETER READING USED AS BASIS	EQUIVALENT GPM	EQUIVALENT LB-MOLS/MIN
35.50	3.060	.3182

BTU/MIN TO UP TO NBP	INTERNAL INCREASE LB-MOLS/MIN	RATE BASED ON REFLUX-LBMOL/MIN
210.30	.0168	.3350

INTERNAL LIQ RATE OVER INTERNAL VAPOR RATE LMM/LMM
.8432

MIDDLE TRAY INFORMATION

TRAY LIQ NBP (F)	TRAY LIQ DEN GM/ML	TRAY LIQ DEN LB/FT3	OPERATING PSI	LIQ COMP MOL PCT
151.7	.7985	49.8246	14.88	41.20

VAPOR LEAVING TRAY FT3/SEC	DENSITY OF VAPOR LBS/FT3	SUPERFICIAL VAPOR FT/SEC
2.462	.158444	2.216

TRAY HOLE AREA FT2	DRY-TRAY PRESSURE DROP IN INCHES OF TRAY LIQ	ACT TRAY PRES DROP - IN. LIQ
.06299	1.2304	3.1310

EFFECTIVE DEPTH OF TRAY LIQ INCHES	TRAY HOLD UP FT3	DOWNCOMER HOLD UP FT3
1.90	.09684	.04051

TOTAL TRAY HOLD-UP FT3	TOTAL TRAY RESIDENCE TIME IN MINUTES	REBOILER HOLD-UP OVER TOT TRAY HU
.13735	.3468	41.1

TOTAL TRAY HU IN MOLS	TRAY DECK HU IN MOLS
.09796	.06907

ELD ALLOWABLE VAPOR RATE FT3/SEC	PCT THAT ACTUAL RATE IS OF ELD	LIQ AVG MOL WT
2.909	84.63	69.86

LIQUID RATE GPM	VAPOR F FACTOR (FT/SEC)SQRTLB/FT3	LIQ RATE IN GPM/WEIR-FT
2.963	1.102	4.444

TRAY DECK RESIDENCE TIME IN SEC 14.670

SUPERFICIAL GAS VEL IN 16 BY 8 AREA FT/SEC 2.770

TOP TRAY HOLD-UP

TOP TRAY DECK HOLD-UP LB-MOLS .0724

TOP TRAY TOTAL HOLD-UP LB-MOLS .1027

BOTTOM TRAY HOLD-UP

BOTTOM TRAY DECK HOLD-IP LB-MOLS .0650

BOTTOM TRAY TOTAL HOLD-UP LB-MOLS .0922

OVERHEAD CONDENSER INFORMATION

COOLING WATER DELTA T (F)	COOLING WATER RATE LBS/MIN	HEAT ABSORBED BY CW BTU/MIN
15.0	305.9	4587.8

DELTA TEMP BY WHICH REFLUX IS SUB-COOLED (F)	HEAT REMOVED FROM VAPOR BY OH CONDENSER BTU/MIN
15.87	3625.78

REBOILER INFORMATION

HEAT INTO REBOILER (BASED ON VAPOR RATE FROM REFLUX) BTU/MIN	REBOILER HOLD-UP FT3	REBOILER HOLD-UP GALS
4485.3	5.65	42.276

DATA CARDS USED IN ABOVE CALCULATIONS

```
      46 3.0 15.0 6.45    3120.077.2030.0064.7035.50
   71.10 7.1030.80124.841.20 5.0070.00 .094 329.
    2.50  1.5 4.386.80013.50
```

APPENDIX E

A FORTRAN II PROGRAM FOR THE LEAST SQUARES FIT OF A DECAYING EXPONENTIAL CURVE WITH TWO PARAMETERS

1. LIST OF STATEMENTS

```
C  C
      DIMENSIONY(25),T(25)
 800  READ69,NRUN,N,TH,TL,DELTA,TDHU,TTHU,RATEL,ID
      A2H=-1./TH
      A2L=-1./TL
 69   FORMAT(2I5,6F10.0,A2)
      DO12J=1,N,1
 12   READ70,Y(J),T(J)
 70   FORMAT(2F10.0)
      M=1
      A2=A2H
  100 FTL=0
      FTR=0
      FBL=0
       FBR =0
      DO13J=1,N,1
      W=EXPF(A2*T(J))
      FTL = FTL +(Y(J) -Y(1))*(1. -W)
      FTR = FTR + (Y(J) - Y(1))  * W * T(J)
       FBL = FBL + (1. -W)**2
   13 FBR = FBR+(1. -W)*W*T(J)
      XN=N
       FA2 =(FTL/FBL) -(FTR/FBR)
      IF(M-2)200,400,600
 200  FA2H=FA2
      M=2
      A2=A2L
      GOTO100
 400  FA2L=FA2
      IF(FA2H)401,431,461
 401  K=1
      IF(FA2L)403,413,501
 403  PRINT404
 404  FORMAT(31HBOTH FA2H AND FA2L ARE NEGATIVE)
      STOP
 413  A2=A2L
      GOTO700
 431  A2=A2H
      GOTO700
 461  K=0
      IF(FA2L)501,473,463
 473  A2=A2L
      GOTO700
 463  PRINT464
 464  FORMAT(31HBOTH FA2H AND FA2L ARE POSITIVE)
```

```
      STOP
501   A2=(A2L+A2H)/2.
      M=3
      GOTO100
600   IF(SENSESWITCH1)700,900
900   IF(FA2)901,700,951
901   IF(FA2+DELTA)902,700,700
902   IF(K)903,904,905
903   STOP
904   A2L=A2
      GOTO501
905   A2H=A2
      GOTO501
951   IF(FA2-DELTA)700,700,952
952   IF(K)953,954,955
953   STOP
954   A2H=A2
      GOTO501
955   A2L=A2
      GOTO501
700   A2C=A2
       A1C =FTR/FBR
      TAU=-1./A2C
       XINT   =   Y(1)
       DX = A1C
       A0C   = XINT   +DX
      PUNCH701,NRUN,ID
701   FORMAT(3X10HRUN NUMBER,I4,10X,2HID,3XA2//)
      PUNCH702
702   FORMAT(8X10HX(INITIAL)2X8HX(FINAL)2X21HTIME CONSTANT
     $ DELTA)
      PUNCH703
703   FORMAT(4X2(4X7HMOL PCT)5X7HMINUTES7X7HXF - XI)
      PUNCH704,XINT,A0C,TAU,DX
704   FORMAT(5X,F9.2,F11.2,F14.3,F12.2//)
      TATD=(TAU*RATEL)/TDHU
      TATT=(TAU*RATEL)/TTHU
      PUNCH1001
1001  FORMAT(2X2(6X16HTIME CONSTANT IN))
      PUNCH1002
1002  FORMAT(7X17HNORMAL    TD   TIME5X16HNORMAL   TT   TIME)
      PUNCH1003,TATD,TATT
1003  FORMAT(1X,2F20.3//)
      PUNCH705
705   FORMAT(8X39HFUNCTION    TOLERANCE ALLOWED   NUMBER OF)
      PUNCH706
706   FORMAT(8X42HOF   A2       IN FUNCTION OF A2   OBSERVATIONS
     $)
      PUNCH707,FA2,DELTA,N
707   FORMAT(5X,E11.4,5X,E11.4,10X,I3//)
      PUNCH708
708   FORMAT(8X39HL1@ RATE    TRAY DECK HU    TOTAL TRAY HU)
      PUNCH709
709   FORMAT(8X36HLBMOL/MIN     LB-MOLS          LB-MOLS)
```

```
      PUNCH710,RATEL,TDHU,TTHU
  710 FORMAT(5X,F11.5,F13.5,F15.5//)
       SDEV=0

  715 FORMAT(9X2(2X7HMOL PCT)5X11HDELTA  TIME3(3X6HNORMAL))
      PUNCH716
  716 FORMAT(13X3HOBS6X4HCALC6X10HXO-XC  MIN7X22HCOMP   TO T
     $IME TT TIME)
      DO720J=1,N,1
       XCAL       = XINT + A1C *(1.  -EXPF(A2C*T(J)))
      XNOR=(Y(J)-XINT)/(A0C-XINT)
      DELX=Y(J)-XCAL
      TDDT=(RATEL*T(J))/TDHU
      TTDT=(RATEL*T(J))/TTHU
      SDEV=SDEV+DELX*DELX
  720 PUNCH717,J,Y(J),XCAL,DELX,T(J),XNOR,TDDT,TTDT
  717 FORMAT(8X,I2,F7.2,F10.2,F10.2,F7.2,F9.2,F9.2,F9.2)
       SE = SQRTF (SDEV/(XN- 3. ))
      PUNCH718,SE
  718 FORMAT(//8X14HSTANDARD ERROR,3XE11.5)
      PUNCH719
  719 FORMAT(1H1)
  725 IF(SENSESWITCH1)730,800
  730 IF((ABSF(FA2))-DELTA)800,800,900
      END
```

2. DEFINITIONS OF VARIABLES USED IN STATEMENTS

A1C=TOTAL CHANGE IN TRAY CONCENTRATION, MOL PCT
A2C=THE NEGATIVE RECIPROCAL OF TAU
A2,A2H,A2L=TRIAL VALUES OF A2C
A0C=FINAL VALUE OF TRAY LIQUID CONCENTRATION, MOL PCT
DELTA=TOLERANCE ALLOWED IN TRIAL AND ERROR SOLUTION
OF LEAST SQUARES EQUATIONS
DELX=DIFFERENCE BETWEEN CALCULATED AND OBSERVED VALUE
OF TRAY CONCENTRATION, MOL PCT
FA2=FUNCTION OF A2
FTR,FTL,FBR,FBL=PORTIONS OF FA2 CALCULATION
ID=TRAY IDENTIFICATION
N=NUMBER OF OBSERVATIONS
NRUN=RUN NUMBER
RATEL=LIQUID FLOW RATE, LB-MOLS/MIN
S1...7=SUMS USED IN LEAST SQUARES FIT
SDEV=SUM OF THE SQUARE OF DIFFERENCE BETWEEN CALCULAT-
ED AND OBSERVED VALUE OF TRAY CONCENTRATION
SE=STANDARD ERROR
T(J)=TIME WHEN Y(J) OBSERVED, MINUTES
TATD=TAU IN NORMALIZED TRAY DECK TIME
TATT=TAU IN NORMALIZED TOTAL TRAY TIME
TAU=SYSTEM TIME CONSTANT
TDDT=NORMALIZED TRAY DECK TIME
TDHU=TRAY DECK HOLD-UP, LB MOLS

TH=ESTIMATED HIGH VALUE OF TAU
TL=ESTIMATED LOW VALUE OF TAU
TTDT=NORMALIZED TOTAL TRAY TIME
TTHU=TOTAL TRAY HOLD-UP, LB MOLS
XCAL=CALCULATED VALUE OF TRAY CONCENTRATION, MOL PCT
XINT=INITIAL VALUE OF TRAY LIQUID CONCENTRATION, MOL PCT
XNOR=NORMALIZED VALUE OF TRAY CONCENTRATION
Y(J)=OBSERVED VALUE OF TRAY CONCENTRATION, MOL PCT

3. TYPICAL COMPUTER PRINT-OUT

RUN NUMBER 104 ID 31

X(INITIAL) MOL PCT	X(FINAL) MOL PCT	TIME CONSTANT MINUTES	DELTA XF - XI
57.86	63.30	5.068	5.44

TIME CONSTANT IN NORMAL TD TIME	TIME CONSTANT IN NORMAL TT TIME
5.941	4.623

FUNCTION OF A2	TOLERANCE ALLOWED IN FUNCTION OF A2	NUMBER OF OBSERVATIONS
-1.3000E-06	5.0000E-06	13

LIQ RATE LBMOL/MIN	TRAY DECK HU LB-MOLS	TOTAL TRAY HU LB-MOLS
.15870	.13537	.17396

POINT	MOL PCT OBS	MOL PCT CALC	DELTA XO-XC	TIME MIN.	NORMALIZED COMP.	VALUE OF TIME(D)	VALUE OF TIME(T)
1	57.86	57.86	0.00	0.00	0.00	0.00	0.00
2	58.36	58.36	0.00	.49	.09	.57	.44
3	59.21	59.18	.02	1.41	.24	1.65	1.28
4	59.94	59.75	.18	2.16	.38	2.53	1.97
5	60.33	60.43	-.10	3.24	.45	3.79	2.95
6	60.91	60.88	.02	4.10	.55	4.80	3.74
7	61.27	61.43	-.16	5.42	.62	6.35	4.94
8	61.90	61.83	.06	6.62	.74	7.76	6.03
9	62.11	62.22	-.11	8.19	.78	9.60	7.47
10	62.59	62.47	.11	9.51	.86	11.14	8.67
11	62.70	62.67	.02	10.89	.88	12.76	9.93
12	62.87	62.83	.03	12.40	.91	14.53	11.31
13	62.93	62.97	-.04	14.19	.93	16.63	12.94

STANDARD ERROR .10577E-00

TD = TRAY DECK, TT = TOTAL TRAY, HU = HOLD-UP, XO = OBSERVED COMPOSITION, XC = CALCULATED COMPOSITION, ID = SAMPLE POINT

APPENDIX F

A FORGO PROGRAM FOR THE CALCULATION OF NEW STEADY STATE TRAY CONCENTRATIONS - REBOILER CONCENTRATION FIXED

1. LIST OF STATEMENTS

```
C  C
      DIMENSION Y(10),X(10)
  100 READ69,NRUN,XR,XT,XM,XB,XREB,RALIQ,RAVAP
   69 FORMAT(I5,5F5.2,2F10.3)
      I=1
      Y(I)=XR
  101 I=I
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      IF(XT-X(I))102,103,103
  102 I=I+1
      Y(I)=X(I-1)
      GOTO101
  103 TI=I
      PART=(Y(I)-XT)/(Y(I)-X(I))
      TTT=TI+PART-1.
  104 IF(XM-X(I))105,106,106
  105 I=I+1
      Y(I)=X(I-1)
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO104
  106 TI=I
      PART=(Y(I)-XM)/(Y(I)-X(I))
      TTM=PART+TI-1.
  107 IF(XB-X(I))108,109,109
  108 I=I+1
      Y(I)=X(I-1)
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO107
  109 TI=I
      PART=(Y(I)-XB)/(Y(I)-X(I))
      TTB=PART+TI-1.
  110 IF(XREB-X(I))111,112,112
  111 I=I+1
```

```
      Y(I)=X(I-1)
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO110
112   TI=I
      PART=(Y(I)-XREB)/(Y(I)-X(I))
       XIRB = XREB
      TTRB=TI+PART-1.
      RABOT=RALIQ-RAVAP
      I=1
400   Y(I)=(RALIQ/RAVAP)*XR-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
116   XI=I
113   IF(TTT-XI)115,115,114
114   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO116
115   PART=TTT+1.-XI
       IF(I-1) 370,370,369
370   XNT = XR - PART*(XR    - X(I))
      DXT = XT - XNT
      GO TO 117
369   XNT=X(I-1)-PART*(X(I-1)-X(I))
      DXT = XT - XNT
117   IF(TTM-XI)119,119,118
118   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
      GOTO117
119   PART=TTM+1.-XI
      XNM=X(I-1)-PART*(X(I-1)-X(I))
      DXM = XM - XNM
120   IF(TTB-XI)122,122,121
121   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
```

```
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
      GOTO120
122   PART=TTB+1.-XI
      XNB=X(I-1)-PART*(X(I-1)-X(I))
      DXB = XB - XNB
123   IF(TTRB-XI)125,125,124
124   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
125   PART=TTRB+1.-XI
      XNREB=X(I-1)-PART*(X(I-1)-X(I))
      DXREB = XIRB - XNREB
404   PUNCH200,NRUN
200   FORMAT(17X11HRUN  NUMBER2XI5//)
       PUNCH 303
303   FORMAT(6X40HCALCULATIONS ARE MADE FROM TOP TO BOTTOM//
     $)
      PUNCH 304
304   FORMAT(6X48HREBOILER COMP IS ASSUMED UNCHANGED IN OP L
     $INE EQ//)
      PUNCH201
201   FORMAT(6X8HLIQ RATE7X10HVAPOR RATE7X12HBOTTOMS RATE)
      PUNCH202
202   FORMAT(7X6HLM/MIN10X6HLM/MIN12X6HLM/MIN)
      PUNCH203,RALIQ,RAVAP,RABOT
203   FORMAT(6X,F7.4,9X,F7.4,11X,F7.4//)
      PUNCH204
204   FORMAT(20X29HINITIAL    THEORETICAL    FINAL)
      PUNCH205
205   FORMAT(21X4HCOMP8X5HTRAYS6X4HCOMP5X7HXI - XF//)
      PUNCH206,XR
206   FORMAT(6X6HREFLUX8XF5.2//)
      PUNCH207,XT,TTT,XNT,DXT
207   FORMAT(6X8HTOP TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH208,XM,TTM,XNM,DXM
208   FORMAT(6X8HMID TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH209,XB,TTB,XNB,DXB
209   FORMAT(6X8HBOT TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH210,XIRB,TTRB,XNREB,DXREB
210   FORMAT(6X8HREBOILER6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH211
211   FORMAT(1H1)
      GOTO100
      END
```

2. DEFINITION OF VARIABLES USED IN STATEMENTS

DXB=CHANGE IN BOTTOM TRAY COMPOSITION, MOL PCT
DXM=CHANGE IN MIDDLE TRAY COMPOSITION, MOL PCT
DXREB=CHANGE POSSIBLE IN REBOILER COMPOSITION
DXT=CHANGE IN TOP TRAY COMPOSITION
NRUN=RUN NUMBER
PART=PORTION OF A THEORETICAL TRAY
RABOT=EFFECTIVE RATE OF BOTTOMS FLOW, LB-MOLS/MIN
RALIQ=LIQUID RATE AFTER PERTURBATION, LB-MOLS/MIN
RAVAP=VAPOR RATE, LB-MOLS/MIN
TTB=THEORETICAL TRAYS BETWEEN REFLUX AND BOTTOM TRAY
TTM=THEORETICAL TRAYS BETWEEN REFLUX AND MIDDLE TRAY
TTRB=THEORETICAL TRAYS BETWEEN REFLUX AND REBOILER
TTT=THEORETICAL TRAYS BETWEEN REFLUX AND TOP TRAY
X(I)=COMPOSITION OF LIQUID, MOL PCT
XB=BOTTOM TRAY COMPOSITION, MOL PCT BEFORE PERTURBATION
XM=MIDDLE TRAY COMPOSITION, MOL PCT BEFORE PERTURBATION
XNB=NEW BOTTOM COMPOSITION, MOL PCT
XNM=NEW MIDDLE TRAY COMPOSITION, MOL PCT
XNREB=CALCULATED NEW REBOILER COMPOSITION, MOL PCT
XNT=NEW TOP TRAY COMPOSITION, MOL PCT
XR=REFLUX COMPOSITION, MOL PCT BEFORE PERTURBATION
XREB=REBOILER COMPOSITION, MOL PCT
XT=TOP TRAY COMPOSITION, MOL PCT BEFORE PERTURBATION
Y(I)=COMPOSITION OF VAPOR, MOL PCT

3. TYPICAL COMPUTER PRINT-OUT

RUN NUMBER 103

CALCULATIONS ARE MADE FROM TOP TO BOTTOM

REBOILER COMP IS ASSUMED UNCHANGED IN OP LINE EQ

LIQ RATE LM/MIN	VAPOR RATE LM/MIN	BOTTOMS RATE LM/MIN
.1025	.1490	-.0465

	INITIAL COMP	THEORETICAL TRAYS	FINAL COMP	XI - XF
REFLUX	74.74			
TOP TRAY	68.47	.51	52.62	15.85
MID TRAY	41.31	2.15	8.46	32.85
BOT TRAY	12.24	1.81	1.00	11.24
REBOILER	4.00	4.87	.42	3.58

APPENDIX G

A FORGO PROGRAM FOR THE CALCULATION OF NEW STEADY STATE TRAY CONCENTRATIONS - REBOILER COMPOSITION IS ADJUSTED

1. LIST OF STATEMENTS

```
C  C
      DIMENSION Y(10),X(10)
  100 READ69,NRUN,XR,XT,XM,XB,XREB,RALIQ,RAVAP
   69 FORMAT(I5,5F5.2,2F10.3)
      I=1
      Y(I)=XR
  101 I=I
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      IF(XT-X(I))102,103,103
  102 I=I+1
      Y(I)=X(I-1)
      GOTO101
  103 TI=I
      PART=(Y(I)-XT)/(Y(I)-X(I))
      TTT=TI+PART-1.
  104 IF(XM-X(I))105,106,106
  105 I=I+1
      Y(I)=X(I-1)
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO104
  106 TI=I
      PART=(Y(I)-XM)/(Y(I)-X(I))
      TTM=PART+TI-1.
  107 IF(XB-X(I))108,109,109
  108 I=I+1
      Y(I)=X(I-1)
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO107
  109 TI=I
      PART=(Y(I)-XB)/(Y(I)-X(I))
      TTB=PART+TI-1.
  110 IF(XREB-X(I))111,112,112
  111 I=I+1
      Y(I)=X(I-1)
```

```
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO110
112   TI=I
      PART=(Y(I)-XREB)/(Y(I)-X(I))
       XIRB = XREB
      TTRB=TI+PART-1.
      RABOT=RALIQ-RAVAP
      I=1
400   Y(I)=(RALIQ/RAVAP)*XR-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
116   XI=I
113   IF(TTT-XI)115,115,114
114   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      GOTO116
115   PART=TTT+1.-XI
       IF(I-1) 370,370,369
370   XNT = XR - PART*(XR    - X(I))
      DXT = XT - XNT
      GO TO 117
369   XNT=X(I-1)-PART*(X(I-1)-X(I))
      DXT = XT - XNT
117   IF(TTM-XI)119,119,118
118   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
      GOTO117
119   PART=TTM+1.-XI
      XNM=X(I-1)-PART*(X(I-1)-X(I))
      DXM = XM - XNM
120   IF(TTB-XI)122,122,121
121   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
```

```
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
      GOTO120
122   PART=TTB+1.-XI
      XNB=X(I-1)-PART*(X(I-1)-X(I))
      DXB = XB - XNB
123   IF(TTRB-XI)125,125,124
124   I=I+1
      Y(I)=(RALIQ/RAVAP)*X(I-1)-(RABOT/RAVAP)*XREB
      A=((8.3597195E-10*Y(I)-2.5483473E-07)*Y(I)+2.7541477E-
     $05)*Y(I)
      B=((A-1.2418429E-03)*Y(I)+2.8621176E-02)*Y(I)+1.375274
     $1E-01
      X(I)=B*Y(I)+7.1358492E-02
      XI=I
125   PART=TTRB+1.-XI
      XNREB=X(I-1)-PART*(X(I-1)-X(I))
      DXREB = XIRB - XNREB
401   IF(XNREB) 402,402,403
402   XNREB =0
403   IF(ABSF(XNREB - XREB) -.01) 404,404,405
405   XREB = XNREB
      I=1
      GO TO 400
404   PUNCH200,NRUN
200   FORMAT(17X11HRUN  NUMBER2XI5//)
       PUNCH 303
303   FORMAT(6X40HCALCULATIONS ARE MADE FROM TOP TO BOTTOM//
     $)
      PUNCH201
201   FORMAT(6X8HLIQ RATE7X10HVAPOR RATE7X12HBOTTOMS RATE)
      PUNCH202
202   FORMAT(7X6HLM/MIN10X6HLM/MIN12X6HLM/MIN)
      PUNCH203,RALIQ,RAVAP,RABOT
203   FORMAT(6X,F7.4,9X,F7.4,11X,F7.4//)
      PUNCH204
204   FORMAT(20X29HINITIAL    THEORETICAL    FINAL)
      PUNCH205
205   FORMAT(21X4HCOMP8X5HTRAYS6X4HCOMP5X7HXI - XF//)
      PUNCH206,XR
206   FORMAT(6X6HREFLUX8XF5.2//)
      PUNCH207,XT,TTT,XNT,DXT
207   FORMAT(6X8HTOP TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH208,XM,TTM,XNM,DXM
208   FORMAT(6X8HMID TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH209,XB,TTB,XNB,DXB
209   FORMAT(6X8HBOT TRAY6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH210,XIRB,TTRB,XNREB,DXREB
210   FORMAT(6X8HREBOILER6X,F5.2,8X,F4.2,7X,F5.2,5X,F5.2//)
      PUNCH211
211   FORMAT(1H1)
      GOTO100
      END
```

2. DEFINITION OF VARIABLES USED IN STATEMENTS

THESE DEFINITIONS ARE IDENTICAL TO THOSE USED IN APPENDIX F

3. TYPICAL COMPUTER PRINT-OUT

RUN NUMBER 103

CALCULATIONS ARE MADE FROM TOP TO BOTTOM

LIQ RATE LM/MIN	VAPOR RATE LM/MIN	BOTTOMS RATE LM/MIN
.1025	.1490	-.0465

	INITIAL COMP	THEORETICAL TRAYS	FINAL COMP	XI - XF
REFLUX	74.74			
TOP TRAY	68.47	.51	51.92	16.55
MID TRAY	41.31	2.15	7.44	33.87
BOT TRAY	12.24	3.81	.53	11.71
REBOILER	4.00	4.87	.12	3.88

APPENDIX H

A FORGO PROGRAM FOR THE CALCULATION OF OVERALL TRAY EFFICIENCY AT TOTAL REFLUX

1. LIST OF STATEMENTS

```
C  C
      DIMENSION X(10),Y(10)
  100 READ69,NRUN,X(1),IDB,XT,IDT,PLATE
   69 FORMAT(I5,F6.2,A4,F6.2,A4,F5.0 )
      I=1
  500 A=((-3.3167081E-10*X(I)+1.1395702E-07)*X(I)-1.6687152E
     $-05)
      B=((A*X(I)+1.4117442E-03)*X(I)-7.5715889E-02)*X(I)
      Y(I)=(B+3.0597979E-00)*X(I)+2.3275131E-01
      X(I+1)=Y(I)
      IF(X(I+1)-XT)200,300,300
  200 I=I+1
      GOTO500
  300 PART=(XT-X(I))/(X(I+1)-X(I))
      XI=I-1
      TT=XI+PART
      EO=(TT/PLATE)*100.
      PUNCH400,NRUN
  400 FORMAT(6X10HRUN NUMBER,I5//)
      PUNCH401
  401 FORMAT(6X2(5X14HLIQUID MOL PCT))
      PUNCH402,X(1),XT
  402 FORMAT(15X,F5.2,15X,F5.2)
      PUNCH403
  403 FORMAT(16X2HAT18X2HAT)
      PUNCH404,IDB,IDT
  404 FORMAT(15X,A4,16X,A4//)
      PUNCH405
  405 FORMAT(11X12HACTUAL TRAYS6X17HTHEORETICAL TRAYS)
      PUNCH406,PLATE,TT
  406 FORMAT(15X,F2.0,18X,F5.2//)
      PUNCH407
  407 FORMAT(11X33HOVERALL TRAY EFFICIENCY (PERCENT)
      PUNCH408,EO
  408 FORMAT(22X,F6.2)
      PUNCH409
  409 FORMAT(1H1)
      GOTO100
      END
```

2. DEFINITION OF VARIABLES USED IN STATEMENTS

EO = OVERALL TRAY EFFICIENCY
IDB = TRAY IDENTIFICATION OF X(1)
IDT = TRAY IDENTIFICATION OF XT

NRUN = RUN NUMBER
PART = PORTION OF A THEORETICAL TRAY
PLATE = NUMBER OF ACTUAL TRAYS SEPARATING X(1) AND XT
TT = THEORETICAL TRAYS SEPARATING X(1) AND XT
X(1) = LIQUID MOL PCT AT LOWER POINT IN COLUMN
X(I) = LIQUID COMPOSITION, MOL PCT
XT = LIQUID MOL PCT AT UPPER POINT IN COLUMN
Y(I) = VAPOR COMPOSITION, MOL PCT

3. TYPICAL COMPUTER PRINT-OUT

RUN NUMBER 116

LIQUID MOL PCT		LIQUID MOL PCT
12.33		43.08
AT		AT
5		3

ACTUAL TRAYS	THEORETICAL TRAYS
2.	1.68

OVERALL TRAY EFFICIENCY (PERCENT)
84.03

AUTOBIOGRAPHY

The author was born July 10, 1934, in St. Louis, Missouri. His family moved to Mississippi in 1939, and he received his elementary and secondary education in the public school system of Clinton, Mississippi. In 1956 he received the degree of B.S. in Chemical Engineering from the University of Mississippi. The following three years were spent as an Engineering Officer in the U.S. Navy aboard the USS Valley Forge (CVS-45). After being released from active duty, he worked for one and one half years as a chemical engineer for the Chemical Division of the Pittsburgh Plate Glass Company in Lake Charles, Louisiana. In September, 1960, he entered the Graduate School of Louisiana State University where he received the degree of M.S. in Chemical Engineering in January, 1962. At present he is a candidate for the degree of Doctor of Philosophy in Chemical Engineering at that same institution.

EXAMINATION AND THESIS REPORT

Candidate: Paul Whitfield Murrill

Major Field: Chemical Engineering

Title of Thesis: "The Transient Response of a Distillation Column to Liquid Rate Perturbations"

Approved:

Jesse Coates
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

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J B Gardner

F. R. Groves Jr.

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Date of Examination:

May 14, 1963